EVALUATION OF EQUIPMENT AND PROCESSES TO SAMPLE OFFSHORE PLACER DEPOSITS FROM SMALL FISHING VESSELS

VOLUME I

FINAL REPORT
BY:

NORDCO LIMITED

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EXECUTIVE SUMMARY

Although Canadian offshore placer deposits are recognized as an important potential source of gold and other minerals, the lack of appropriate exploration sampling equipment has tended to hamper development of these resources. This report gives the results of a study related to sampling and processing of gold-bearing offshore placer deposits on the Scotian Shelf, carried out for the Canada Centre for Mineral and Energy Technology (CANMET), with funding provided under the Canada-Nova Scotia Economic and Regional Development Agreement.

The report is presented in two volumes. Volume I gives full details of the study including Terms of Reference; a review of the geologic factors controlling the occurrence of marine placers; results of mineralogical testing on bulk samples of low grade gold-bearing sand and gravel; an assessment of the suitability of existing drilling systems for sampling offshore placer deposits; and recommendations for further work. Volume II gives details of the drilling/sampling systems which were evaluated as part of the study, together with a list of suppliers of the equipment.

A primary objective of the study was to investigate drilling/sampling devices which may be suitable for use on otherwise inactive coastal fishing vessels for sampling of offshore placer deposits on the inner portion of the Scotian Shelf, so as to decrease the cost of exploration and create employment opportunities for Canadian fishermen.

This objective imposes severe and, in some cases, conflicting limitations on the key features of sampling systems in the present context. For example, on the one hand atmospheric and oceanographic conditions require that equipment for sampling placer deposits on the Scotian Shelf should be suitable for operation in a relatively harsh marine environment. Also, geologic conditions require that the system

should preferably be able to sample a wide range of soil types ranging from silt or clay to coarse gravel to a depth of 20 to 30 m below seabed. Moreover, the system should preferably also be able to sample the base of the sediment layer and the upper portion of the underlying bedrock, where this interface is located within the depth capabilities of the equipment. On the other hand, the objective of operating the sampling equipment from a small fishing vessel tends to impose limitations on the capital and operating costs, and on the size, weight and complexity of the drilling/sampling system.

Examination of the available data on existing sampling systems evaluated as part of this study has clearly demonstrated that no single system can satisfy all of the project objectives. Nevertheless, an attempt has been made to select existing equipment which most nearly meets revised objectives for Reconnaissance Surveys (Category 1) and for Detailed Investigations (Category 2), as defined in the report. Because there appears to be little published factual data on the performance of the equipment in sampling placers or placer-like deposits, the equipment evaluation has been based primarily on manufacturer's literature and data. In view of this, it is recommended that comparative field trials should be carried out with selected systems to validate the current assessment and to provide crucial field performance data on the suitability of the various drilling/sampling systems in the context of this project. The cost of a three-week field program for this purpose, together with associated mineralogical testing etc., is estimated to be on the order of $400,000.

It is also recommended that consideration be given to development of a purpose-built placer sampling system designed to cater to the environmental and geological conditions which exist in Canadian coastal areas. It is considered likely that such a system could also be marketed outside Canada. Several drilling/sampling systems and concepts which warrant consideration in this connection are identified in the report. Since the trials could provide valuable information on the suitability of various drilling and sampling concepts to meet the objectives of this project, it is recommended that the comparative field trials with selected equipment should be undertaken even if the intention is to proceed with development of a new sampling system.

Further work is needed before it is possible to draw any meaningful conclusions concerning suitable mineralogical processing techniques for marine placers. Also, additional research into the development of onboard processing equipment suitable for operation on a barge or small fishing vessel is needed.

Availability of an effective system capable of providing representative samples of the in-situ material is considered to be an essential prerequisite for carrying out any meaningful exploration of the placer resources offshore Nova Scotia. Because of this, it is recommended that the additional work aimed at developing a suitable sampling system should be carried out prior to undertaking the proposed reconnaissance exploration program. Recommendations are given on factors which should be taken into account in design of the exploration program once a suitable sampling system has been developed.

1.0 INTRODUCTION AND BACKGROUND

A "placer deposit" may be defined as "a surficial mineral deposit formed by mechanical concentration of mineral particles from weathered debris. The mechanical agent is usually alluvial but can also be marine, eolian or glacial." (Dictionary of Geological Terms). Because of its relatively high density (19.3 g/cc), detrital gold often occurs in placer deposits which may be located onshore or offshore.

Placer deposits have been the source of, and continue to yield, over half the world's gold, although this proportion does not hold for North America alone (Coggin 1986). Traditionally, placer gold production has been from on-land deposits. Although, it is known that extensive heavy metal placer deposits, including gold, exist offshore (Balzer 1986), the problems associated with prospecting in a marine environment have generally made it unattractive to an industry which has been essentially land based. The increased level of effort required for marine operations, and the lack of appropriate sampling equipment for exploring potential offshore placer deposits, have tended to discourage efforts in this direction.

Despite these factors, there is current interest in exploring for gold, tin and other heavy minerals in offshore placers off Canada's east coast, and elsewhere (Hale and McLaren 1984; Hopkins 1985; Miller et al. 1985; Samson 1984).

In this connection, earlier work (e.g. Hopkins 1985) had indicated to the Department of Energy, Mines, and Resources that a professional assessment of the following factors was required:

- the suitability and adequacy of available coring and drilling equipment for sampling offshore placer deposits. In order to make use of available and under-utilized facilities it was suggested that drilling and sampling equipment should be suitable for operation by unskilled operators from 30 m (200 tonne) vessels, such as fishing vessels.

- suitable mineral processing and recovery methods and equipment to recover minerals from offshore placer deposits, with particular reference to recovery of gold.

- further definition of offshore placer resources and examination of the potential value of these deposits.

This report presents the results of a study of some of the factors listed above carried out by NORDCO Limited for the Canada Centre for Mineral and Energy Technology (CANMET), under DSS Contract No. 0SQ85-00287 dated January 29, 1986. Funding for this work was provided under the Canada-Nova Scotia Mineral Development Agreement.

The following individuals and companies acted as sub-consultants to NORDCO Limited for this study:

- Assessment of geological factors; Dr. J. Vaughn Barrie and Ms. Margot Emory-Moore, C-CORE, St. John's, Newfoundland.

- Review and evaluation of existing drilling and sampling systems; Dr. Adrian Richards, V.P. Research and Development, Fugro b.v., Leidschendam, The Netherlands; Mr. Jason Goodden, Director, Seacore Limited, Helston, England

- Metallurgical testing and assessment; Witteck Development Inc., Mississauga, Ontario.

This report is presented in two volumes. Volume I provides details of the overall study including Terms of Reference, an overview of the geology of offshore placer deposits, results of metallurgical testing on placer samples, an evaluation of existing drilling and sampling systems and conclusions and recommendations. Volume II provides details of the various existing drilling and sampling systems evaluated.

2.0 TERMS OF REFERENCE

The "Statement of Work" for the project (see Appendix A), includes the following summarized requirements for the study:

> ...."investigate the drilling devices which may be suitable for sampling of offshore placer deposits; process gold bearing samples from offshore placers to determine the mineral processing requirements to recover gold; ... and produce a Statement of Work for a prefeasibility report which describes, engineers and estimates the cost of a twelve (12) month exploration program, drilling and sampling placers from a small fishing vessel."

The present work comprises Phases I and II of a proposed three phase program as follows:

> "Phase I - Compile information on offshore Placer Drilling Equipment. The contractor will produce a comprehensive report assessing the capability and suitability of available drilling technologies that might be used for placer exploration in the Canadian offshore. The report should also include costs and terms of purchase/lease of the various systems examined as well as suppliers. Recommendations will be made on possible improvements and the potential for modifying existing equipment for use on coastal fishing vessels so as to decrease the cost of exploration and create employment opportunities for Canadian fishermen. As an additional requirement of this report, the Contractor shall prepare a Statement of Work and cost proposal for the Phase III section of this project. This Statement of Work will address the requirements for preparing a feasibility report with engineering and costs data describing sample recovery systems and sampling programs. This Statement of Work will include a cost proposal to complete this work."

"Phase II - Determine the Processing Requirements for Offshore Placer Reserves. The contractor will arrange to process four (4) bulk placer gold samples presently being recovered from private offshore exploration work. The processing studies will identify the mineral associations, and determine the optimum recovery methods using gravity, flotation and magnetic separation mineral processing techniques."

"Phase III - (not included in the present work) - Feasibility report with engineering and cost data describing the sample recovery systems and sampling program. The contractor will build upon the information generated by Phase I and II and will produce a prefeasibility report... This report would describe the design of a sample recovery system which may consist of two (2) types of drilling-coring systems capable of being mounted onto a small fishing vessel or barge, an on-board sample processing system to recover minerals from the drill cores, and outline an exploration program to provide an overview of the placer mineral reserves off-shore Nova Scotia. The study would be of sufficient detail to enable interested parties to commence an effective exploration program."

3.0 GEOLOGICAL OVERVIEW

The geological factors which control the genesis, occurrence and character of marine gold placer deposits, with particular reference to the inner portion of the Scotian Shelf (water depths <100 m), are summarized here. A more complete discussion is provided in Appendix B. This geological information is essential when assessing or developing drilling/sampling and processing systems to be used in the offshore environment and when designing a viable exploration program.

Three factors are needed for the development of any gold placer: 1) a source; 2) liberation of the gold from the source by mechanical or chemical means; and 3) a means of concentrating the gold.

A thick sequence of quartzites and slates, known as the Meguma Group, along with minor granitic bodies characterize the bedrock geology off Nova Scotia and represent an extension of the geology on land (King and MacLean 1976). The Meguma Group is known to host gold in auriferous quartz veins onshore and, by extrapolation, at least 50 favourable sites for gold mineralization are believed to exist offshore (Fowler and Miller 1985). This is the source for possible Scotian Shelf marine placers.

During the Wisconsin glacial stage (300,000 to 10,000 yBP) glacial ice covered much of Nova Scotia, extending to the outer edge of the present continental shelf (King and Fader 1985). To a point 30-50 km from the present shoreline, this ice was grounded (King 1970) and a combination of glacial quarrying and meltwater erosion by sub- and pro-glacial streams helped to create the highly irregular bedrock morphology which now characterizes the inner Scotian Shelf (Piper et al. 1985). These processes represent the mechanical means whereby gold could be liberated from auriferous Meguma Group bedrock.

Sediment entrained by the glaciers was redeposited as a blanket of glacial drift, or till, across most of the inner shelf area. With recession of the ice sheet, the entire shelf experienced a period of isostatic rebound, which lowered relative sea level by roughly 120 m, followed by a transgressive period when relative sea level gradually returned to its present position. The present surficial sediment distribution on the inner Scotian Shelf is in large part the result of glacial drift "unmixing" through marine reworking during the transgression. Collectively, the surficial sediments are known as the Sable Island Sand and Gravel Formation (King 1970). Emory-Moore (1985) has recognized four individual textural facies on the inner shelf (Table 3.1, Figure 3.1). Facies 1 represents the original blanket of glacial drift (Scotian Shelf Drift, King (1970)) that was deposited during the advance and retreat of glacial ice over the shelf during the Wisconsin Stage. Facies 2 represents the coarse gravel end-member of the glacial drift and is stable (i.e. forms a pebble armour) under present marine conditions. Facies 3 is presently being "unmixed" with sediment mobility restricted to the sand subfacies. Upon further sea level transgression and subsequent marine reworking, facies 3 should acquire the characteristics of facies 2 (i.e. become a gravel lag deposit). Finally, facies 4 is a blanket of modern sand with minor mud (note mud is restricted in occurrence to protected embayments) which are highly mobile and continually moved shoreward with the transgressing sea. Facies 4 is the finer end-member of the original "unmixed" glacial drift.

The combination of locally auriferous bedrock, eroded by glacial and fluvial action to produce a blanket of surficial sediment which was then reworked by high energy marine processes leads to five distinct possible types of marine gold placers on the Scotian Shelf. Table 3.2 summarizes the characteristics of the five placer types.

"Glaciomarine" placers represent deposits of glacial drift (Facies 1, Table 3.1) which contain anomalous concentrations of gold derived from underlying auriferous bedrock. As such, this type of deposit is not a placer in the strictest sense since there has been no concentration of the gold. Such deposits are known to exist onland and always occur close to bedrock sources because sediment entrained

	Facies 1	Facies 2	Facies 3	Facies 4
Mean grain size (mm) (max-min)	.5 (64-.05)	16 (64-4)	2.4 (8-1)	.125 (.25-.0625)
Mean Sorting	.8-4 (moderate-very poorly)	1.2 (poorly)	2.5 (very poorly)	2.8 (very poorly)
Mineralogy	-quartzite -slate -granite -basalt -quartz, mica and feldspar	~ 70% quartzite ~ 20% slate ~ 8% granite ~ 2% misc.	80-90% quartz	~ 65% quartz ~ 15% feldspar ~ 10% mica
Thickness (m)	0-100 (avg. ~ 15)	0-10	0-10	0-5
Water Depths (m)	0-100	10-100	0-60	0-19
Present Mobility*		< 13 m	< 24 m coarse < 38 m fine	< 39 m
References	King (1976)	Emory-Moore (1985)	Emory-Moore (1985)	Emory-Moore (1985)

Characteristics of Scotian Shelf Sediments

* This is a measure of the maximum water depth at which a given sediment will move under storm conditions (assumed T = 7 sec, H = 4 m).

TABLE 3.1

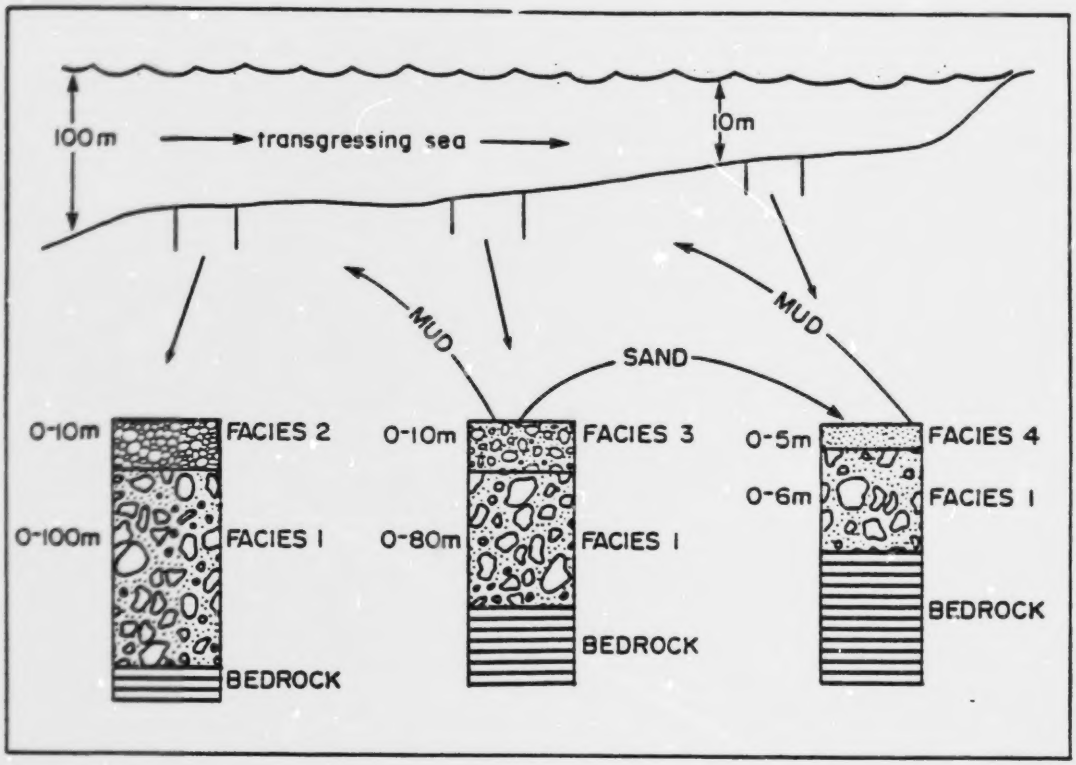

100m
transgressing sea
10m
MUD
MUD
SAND
0-10m
FACIES 2
0-100m
FACIES 1
BEDROCK
0-10m
FACIES 3
0-80m
FACIES 1
BEDROCK
0-5m
FACIES 4
0-6m
FACIES 1
BEDROCK

FIGURE 3.1 Stratigraphy of Scotian Shelf Sediments(After Emory-Moore,1985).

	glaciomarine	lag deposits	glaciofluvial	relict alluvial	submerged beach
mean grain size (mm)	.05-1	16	4-16	4-16	.35
mean sorting	.8-4 (moderate-poorly)	1.2 (poorly)	1.5 (poorly)	1.5 (poorly)	.5 (poorly)
mineralogy	See facies 1, Table 1	See facies 2, Table 1			
overburden thickness	5-10m	0m	5-10m	10-100m	0-10m
facies thickness	1-90m	10m	25m	10m	5m
depth to bedrock	0	0-90m	0-60m	0-3m	0-90m
gold:-source	allocthonous	allocthonous and/or autochthonous	allocthonous	allocthonous	alloctonous
-size(mm)	<.0625 (flake)	<.0625	<.0625-.25	.25	<.0625 (flake)
-grades	10-100 pb	>500ppb			
preservation potential	high	high	high	low	high

TABLE 3.2 **Placer Characteristics**, Scotian Shelf

by glacial ice was generally carried only a short distance (<2 km) before being redeposited (Grant 1963).

Drift deposits on the Scotian Shelf are highly variable in thickness, ranging from almost nil over bedrock highs to as much as 100 m in fiord-like bedrock depressions. The drift itself is generally poorly sorted (grain size ranging between >64 mm to <.05 mm) and overconsolidated (undrained shear strength on the order of 45 kPa (King and Fader 1985)). These characteristics make drift deposits difficult to sample by conventional means.

Of the four surficial facies recognized on the inner Scotian Shelf (Table 3.2), the lag gravels (Facies 2) have been found in coastal areas to contain concentrations of gold where auriferous drift deposits have been reworked (Emory-Moore 1985). The gold in this type of deposit (see Table 3.2) is generally fine grained (<.0625 mm) and concentrated within the top few metres of sediment. It has been suggested that in some cases the gold will concentrate at the interface between the reworked gravels and the underlying material, be it till or bedrock.

A multitude of ancient fluvial channels, which are evident on detailed bathymetric charts and high-resolution geophysical data collected on the inner Scotian Shelf, are potential sites for "relict alluvial" placer deposits (Table 3.2). In many cases this type of deposit will have been eroded and removed by glacial ice. However, where preserved, these placers may be fairly close to the seabed, covered only by a thin coating of post-glacial sand or mud, or they could be buried under tens of metres of glacial drift. In either event, the gold in this type of deposit would be expected to be fine-grained (<.0625 mm) and associated with loose gravels or coarse sands close to the base of the fluvial channel.

Another type of fluvial placer, produced by sub- or pro-glacial streams ("glaciofluvial placer," see Table 3.2), has essentially the same physical characteristics as "relict alluvial" placers. However, glaciofluvial placer deposits will generally be thicker and closer to the surface, and may be found at greater distances from the source. A potential placer deposit offshore from Country Harbour may represent this type of deposit.

The final possible type of placer to be expected on the Scotian Shelf is the "submerged beach" placer (Table 3.2). The incremental nature of the post-glacial transgressive event produced a number of beach terraces and sea scarps which may contain anomalous concentrations of gold, similar to present day coastal occurrences (Samson 1984). These are generally loose, gravelly deposits which are on the order of a metre or two in thickness and less than 100 m in width. The gold is again found to be fine-grained and in close association with basal gravels. These deposits, as with the glaciofluvial and lag placers, exist near the present seabed.

In addition to the relict placer deposit types outlined above, it should be mentioned that modern high-energy marine processes such as waves, strong currents and ice are also capable of producing and constantly shifting placer deposits in nearshore areas of Nova Scotia. Examples exist where millions of cubic yards of gold bearing sediment, delineated by a sampling program one year, were not found the next, presumably because of the action of waves and currents generated by severe winter storms (Samson 1984). Again, these are gravelly to sandy (lag-type) surficial deposits with associated fine-grained gold.

To summarize, a number of factors need to be considered when assessing sampling systems and processing techniques to be used for marine placer exploration on the Scotian Shelf. First, existing evidence indicates that the gold in any given placer will be primarily fine-grained in nature (particle size of .0625 mm or smaller). This does not, however, rule out the possibility of finding nuggets of gold, or disseminated gold in larger fragments of gold-bearing bedrock (see Section 4.0 of this report). Second, three of the five possible placer types described above (lag, glaciofluvial and relict beach placers) will exist within 10 m of the seabed and therefore will be easily reached by a relatively compact sampling system. All three, however, are primarily loose, gravelly deposits making sample retention, especially of the fine, gold-bearing component, a potential problem. Third, due to the over-compacted, bouldery, and, in certain cases, thick nature of tills on the Scotian Shelf, "glaciomarine" type placers will only be successfully sampled by relatively large, expensive and sophisticated systems. Similarly, these types of systems will be required to reach "relict alluvial" type placers when they are covered by till. The generally low-grade concentrations of gold expected in "glaciomarine" placers (see Table 3.2) also means that large samples of the material will be required to yield meaningful results, whereas smaller samples, may suffice for the more concentrated placer types. Finally, the drilling sampling system(s) selected may be required to penetrate and sample the base of the sediment layer and the upper 200 to 300 mm of the underlying bedrock in the case of lag deposits.

4.0 METALLURGICAL TESTING

Full details of metallurgical testing carried out by Witteck Development Inc. on three bulk samples of low grade gold-bearing placer sand and gravel (collected from Nova Scotian beaches and supplied by the client), together with test results and conclusions and recommendations based on this work, are given in Appendix C. This portion of the work was severely hampered by the low gold content of the samples provided for test.

The objectives of the test program were to identify the mineral associations and determine the metallurgical process which would result in optimum recovery of the gold. A processing method for the bulk samples was developed to provide the requested metallurgical data. The data produced from the program included:

- accurate gold assays
- distribution of gold with particle size
- metallurgical balances for upgrading by gravity processing
- identification of mineralogical associations and characterization of gold mineralization
- metallurgical balances for processing by flotation and leaching
- evaluation of data and preliminary flowsheet conceptualization

Gold head analyses were completed for the bulk samples by using a multiple sample assay technique. The head assays for bulk samples A, B and C were 0.16, 0.15 and 0.05 g/t gold respectively.

Distribution of gold by size fraction (see Tables 2 to 4 of Appendix C) indicates the presence of gold concentration in the finer fractions of the A and B samples and in the coarse fraction (+6 mesh to 25 mm) of all three samples. The small sample size provided did not permit repetition of testing to check the test results measured on the coarse fractions. Preconcentration by screening was successful in upgrading Samples A and B. Sample C was of lower grade and preconcentration was not warranted.

Upgrading by gravity processing on one quarter of the A and B sample showed promising preliminary results. Tabling and vanning results were good but due to the fineness of the gold, jigging produced poor results. Jig test recovery of gold varied from 3.2 to 27.9%. Table and vanning test results varied from 16.2 to 76.5% gold recovery. These recoveries are based upon the samples tested and are not calculated from the ore prior to preconcentration.

Subsequent metallurgical testwork involving gravity, flotation and leaching of the fourth quarter of Samples A and B indicated the following:

(i) Recovery of gold from the -28, +65 mesh ore fraction by jigging was less than 1.0%.

(ii) Recovery of gold from the -65 mesh ore fraction was 78.4% by tabling, 30.7 to 58.9% by flotation, 94.7% by vanning and 91.0 to 99.0% by cyanidation.

These recoveries are based upon the feed subsequent to preconcentration.

Due to the small sample size provided, it was impossible to perform an adequate number of tests in each of the metallurgical areas. It was also impossible to provide complete mass balances for some of the tests, because of the 30 gram sample requirements for low grade ore and the amount of several of the concentration products.

The mineralogical identification of particles in various metallurgical products indicated minor sulfides, chloritized ferromagnesian minerals, quartzofeldspathic particles and various other minerals. Gold mineralization was observed as 70-75 micron irregular winglike placer particles with smooth grain boundaries.

5.0 EVALUATION OF EXISTING DRILLING AND SAMPLING SYSTEMS

It is essential that the criteria which are to be used in judging and evaluating the various existing drilling and sampling systems be developed prior to the review of these systems. Several of the project objectives concerning drilling/sampling systems tend to conflict, such as the geological requirements relating to sample size and exploration depth capability of the sampling system versus the requirement that "the equipment be suitable for use on coastal fishing vessels so as to decrease the cost of exploration and create employment opportunities for Canadian fishermen." In establishment of the overall evaluation criteria, trade-offs and compromises between the various interrelated project criteria and objectives have been necessary. The following sections outline this process.

5.1 DEVELOPMENT OF EVALUATION CRITERIA

5.1.1 Geological Considerations

The geological overview (see also Section 3 and Appendix B) indicates that gold bearing placer deposits may exist to a depth of as much as 100 m below seabed. However, following discussions with the client, it has been assumed for present purposes that the depth to which exploration of offshore placers is required will be limited to the depth capabilities of dredging techniques currently used for offshore placer extraction - i.e. a combined water depth and subseabed depth of about 60 m. Moreover, in the present context the maximum practical subseabed dredge depth is considered to be about 20 to 30 m, irrespective of water depth. The drilling system should thus be capable of obtaining samples of the upper few metres of sediment in water depths up to 60 m, while in shallower water sampling to depths of up to 20 to 30 m below seabed is desirable.

The drilling/sampling equipment will also be required to operate within a wide variety of soil types ranging from coarse silt (ca. 0.0 mm grain size) to coarse gravel (ca. 65 mm grain size). In som locations gold may occur in glacial drift deposits, which include a fine silt to clay sized component. It is anticipated that, in places, a surficial armouring layer of cobbles (grain size 75 to 305 mm) may be found overlying offshore placer deposits. In certain cases it may not be necessary that the placer sampling system be capable of sampling the cobble layer, but it should be able to "punch through" the cobbles and sample the underlying material.

As indicated in Tables 2, 3 and 4 of Appendix C, a significant amount of gold was found in both the fine fraction (<100 mesh) and the coarse fraction (+6 mesh to 25 mm) of the samples provided for testing. The gold content of the coarse fraction of the samples tested may be anomalous. Unfortunately, the size of sample provided did not allow for repetition of testing to check this. For the time being, it is considered that these results should not be discounted. The drilling/sampling system(s) selected for subsequent phases of this project should ideally be capable of obtaining representative samples of materials ranging in size from coarse silt (or fine sand) to coarse gravel. Preferably, the system(s) should also be capable of sampling the base of the sediment layer and the upper 200 to 300 mm of the underlying bedrock.

5.1.2 Operational Requirements

One of the criteria given in the "Terms of Reference" regarding the selection of existing drilling and sampling systems is that they should be suitable for operation by fishermen from relatively small (gross weight 200 tonnes, length <30m) fishing vessels. In view of this, the following factors are considered significant in comparing various drilling/sampling systems:

- size and weight of the equipment
- cost (lease and/or purchase)
- requirements for electric and hydraulic power supply, water pump, air compressors, etc.

- requirements for cranes, winches, motion compensation systems or other handling equipment
- vessel mooring system requirements
- requirements for skilled operators

5.1.3 Sample Size Required for Processing

Insufficient sample size (i.e. a sample not truly representative of the sediment and constituent economic minerals) may lead to inaccuracies in placer delineation and reserve estimation. Sampling programs and methods must cater to the spatial and particle size distribution of gold. Small diameter boreholes (e.g. <approximately 60 mm) are generally used to ground truth geophysical data with regard to depth of overburden, presence of buried channels and limits of the deposit. Larger diameter boreholes are required for accurate economic determinations.

Variability and uncertainty in the gold particle size which may occur in offshore placers makes it difficult to determine the required sample size necessary for precision and reliability in gold assay. Dimock (1986) recommends a minimum core diameter of 67.5 mm assuming an arbitrarily selected economic cut-off grade of 0.35 ppm (corresponding to 0.011 oz/ton) and an effective gold particle diameter of 250 microns. This was based on data published by Clifton et al. (1969). Mer Resources Limited (1986) used the Wink Vibrocore in 1985 off Lunenburg with reportedly satisfactory results; however to obtain the volume of sample required for analysis, two holes had to be drilled at each site. During the 1986 work, it was planned to bore three holes at each site, which would be equivalent to a single 79.6 mm diameter core. In discussions with EMR personnel, it was indicated that a sample diameter of 100 to 150 mm is preferred for prospecting work in coarse-grained, low-grade deposits. However, if a fine sediment is encountered a diameter of 75 mm should provide meaningful results. For reconnaissance studies, a smaller sample may suffice in delineating areas of potentially high mineral concentration for later detailed exploration surveying.

5.1.4 Environmental Considerations

Atlantic Nova Scotia may be classified as a storm-dominated environment. During the winter months, winds blow offshore and waves are characterized by significant heights of 4 m and periods of 6 to 8 s. During the summer, winds blow from the southwest with significant wave heights averaging 1 to 2 m and periods of < 5 s (Walker 1984). Storm conditions within the nearshore zone of Atlantic Nova Scotia are characterized by wave heights of 5 m and periods of 4-7 s (Vandall 1976). Figure 5.1(a) illustrates the percent of time a given wave height is expected to be exceeded in the exposed nearshore zone (the data is based on yearly averages). Miller et al. (1985) present similar data for a relatively sheltered location in Lunenburg Bay (Figure 5.1(b)).

Longshore and current velocities vary from 5 to 40 cm/s with an average fair-weather velocity of 12 cm/s (Munroe 1980). Tides are semi-diurnal with a mean tidal range of 1.4 metres. Tidal currents are orientated perpendicular to the coast and are characterized by velocities of 25 cm/s (Miller et al. 1985).

During severe ice years Atlantic Nova Scotia is subject to land-fast ice during January and February. This ice reaches maximum thicknesses of 0.45 metres but is generally less than 0.3 metres (Miller et al. 1985).

The intended sampling system must be fully operational in the above environmental conditions.

5.2 EVALUATION CRITERIA

On the basis of the above considerations and requirements, the following design criteria were derived to be used as a general specification to guide the project team during the evaluation of existing equipment and sampling systems.

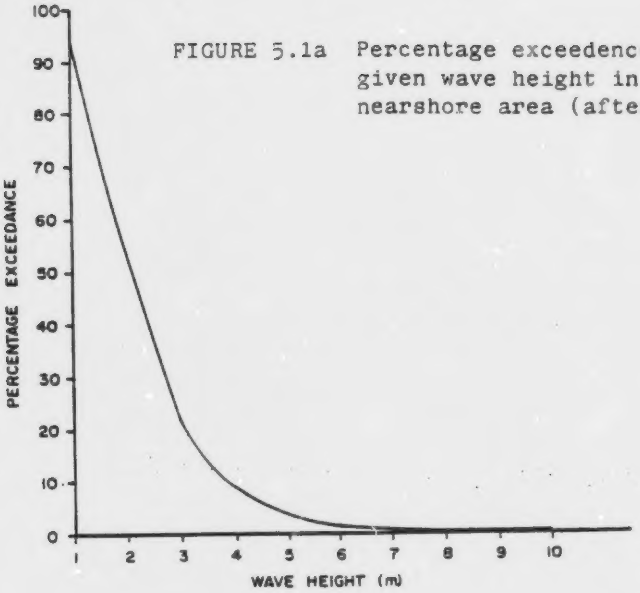


FIGURE 5.1a Percentage exceedence for a given wave height in an exposed nearshore area (after Walker, 1984)

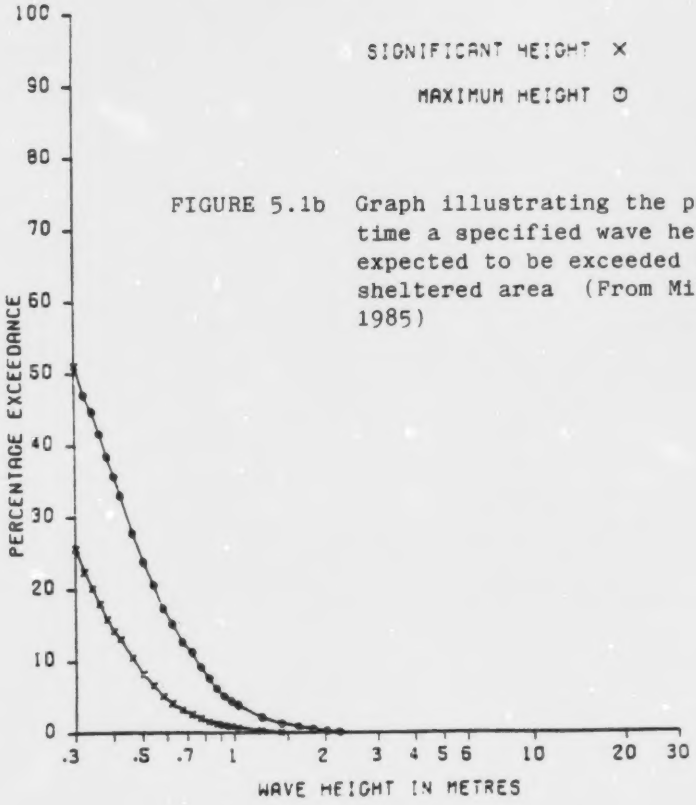


FIGURE 5.1b Graph illustrating the percent of time a specified wave height is expected to be exceeded in a sheltered area (From Miller et al, 1985)

5.2.1 General

(i) Capable of penetrating and sampling a wide range of soil types including clay, silt, sand and gravel up to 40 mm in maximum particle size.

(ii) Recovered samples to be wholly representative of full range of grain sizes present in the in-situ material and, in particular, samples to be free from effects of washout or loss of fines and/or denser particles.

(iii) Capable of recovering continuous or near continuous samples with depth, with original stratigraphy relatively undisturbed. Core recovery to be 80 to 100 percent and samples to be obtained at depth intervals not exceeding 1 m.

(iv) Capable of penetrating a surficial armoring layer of cobbles.

(v) Preferably able to penetrate and sample the upper 200 to 300 mm of bedrock underlying the sediments.

5.2.2 Performance

(i) Preferably capable of sampling 20 to 30 m depth below the seabed.

(ii) Core diameter of 100 to 150 mm is preferred; however, in the finer sediments, a core diameter of 75 mm may be acceptable.

(iii) The target drilling rate is assumed to be 50 m/day with the ability of completing approximately 5 bores/day.

5.2.3 Operational Criteria

(i) Capable of operating in a water depth of up to 60 m.

(ii) Be suitable for operation in conditions to sea state 5 "Beaufort scale" (average wind speed of 19 knots and a significant wave height of 2 m). It is recognized that this will tend to be more a function of the sea keeping characteristics of the survey vessel than of the sampling equipment. Also, surface mounted equipment and seafloor mounted platforms have significantly different requirements regarding the vessel's stability. In general, seafloor mounted platforms with flexible connections to the surface vessel are able to tolerate a greater amount of vessel heave and off-station movement during drilling, than are surface mounted systems. With seafloor mounted platforms, the operations of deploying and recovering the equipment over the side of the vessel is often the limiting factor in bad weather.

(iii) Suitable for operation from a 30 m, 200 tonnes gross weight fishing vessel not equipped with specialized handling equipment.

(iv) Dimensions and weight to be compatible with the requirement that the system be operable from a "small fishing vessel"

- weight not to exceed 2,000 kg
- dimension not to exceed 3 m x 3 m in plan and 7 m overall height

(v) Requirements for ancillary services and equipment in the support vessel be minimal.

(vi) Suitable for operation by relatively untrained labour.

(vii) Preference to be given to equipment which has proven operation experience and reliability.

5.2.4 Economics

(i) Purchase/lease and operating costs to be "reasonable" and compatible with the philosophy of operating equipment from otherwise inactive "small fishing vessels."

5.3 MARINE DRILLING AND SAMPLING SYSTEM TYPES

Because of the conditions prevailing in the ocean environment, the tools and methods of sampling are often different from the techniques used for geotechnical and geological investigations on land. Practical methods for underwater soil sampling are still being developed and there is no universally accepted, ideal system suitable for use in a wide range of soil types. In addition, for many of the systems which are available, there is a minimum of past experience and published performance data to rely upon. Furthermore, a number of systems have been developed by institutions or private companies for undertaking specific projects and are not commercially available.

The equipment presently in use for sampling seabed sediments has been developed to service the needs of three distinctive categories of users.

a) scientific sampling (biological, geological and geochemical);
b) geotechnical engineering; and
c) offshore mining and mineral exploration.

While there is certainly overlap on the information required from samples by these three groups, the constraints on sample recovery are often quite different. In particular the acceptability of the size of sample recovered, the extent of its disturbance and its completeness as a stratigraphic record may differ substantially.

Scientific sampling is aimed at defining the history of sedimentary deposition on the seabed and the corresponding environmental conditions which occurred during the geologic evolution of an area. As such, continuous, undisturbed cores are required. Core diameter is not a limiting factor and relatively small diameter samples will suffice.

Geotechnical investigations are concerned with the engineering properties of the seabed related to the installation of structures, either on shallow or deep (piled) foundations, for such projects as causeways, pipelines, tunnels, bridges, and harbour installations to mention a few. Since these tools are used to remotely sample material to be tested for physical properties, the primary concern for geotechnical sampling is that the sample not be disturbed. Sample size (diameter) is not critical except from the point of view that larger diameter cores will be less disturbed near the centre.

For mineral investigations, it is essential that the samples are of sufficient size to allow accurate qualitative and quantitative assesssment of the mineral content. It is also important that the samples accurately represent the full range of grain sizes and particle densities present in the in-situ material. For this application, however, it is not essential to obtain a continuous, undisturbed sample.

In many cases, remotely operated seafloor mounted equipment is preferred for scientific and reconnaissance surveys aimed at covering many sites over a relatively large area. In comparison with floating equipment, seafloor mounted systems have the advantage of greater mobility, reduced weather dependency, and greater efficiency in deep water applications. It is noted, however, that remotely operated systems do not in all cases supplant more conventional systems supported on some form of floating platform.

5.3.1 Gravity Corers

Gravity and gravity-piston corers are generally used to recover samples from soft unconsolidated soil. Cores up to 30 metres in length have been obtained in muddy materials, however, most good quality cores come from less than 2 metres of penetration with only 20-25 centimeters of core being generally recovered in sand or gravelly sand (Sly 1981). Gravity coring is one of the simplest and most inexpensive methods of coring since the corer is essentially a length of steel pipe with an adjustable weight at the top. Most gravity corers today have an internal piston, hence the name gravity-piston corers. The piston aids in sample recovery and corer penetration by reducing friction and pressure as the sample enters the core barrel. However, sample disturbance is often severe due to compression of the sample as it enters the core barrel.

The corer is lowered over the side of the ship in the vertical position. The trigger line releases the corer at a predetermined distance above the seafloor to enable it to freefall. Upon striking the seafloor the corer penetrates the sediment until the kinetic energy is dissipated by friction and end resistance on the corer.

Several variations of gravity corers have been developed since their first use in the early 1900's. When designing gravity corers the criteria developed by Hvorslev (1949) (i.e. area ratio, outside clearance ratio, etc.) are often followed since they are aimed at producing good penetration with minimum sample disturbance. Similar criteria are appropriate to percussion or vibratory corers.

Since gravity corers have limited capability and are mainly used in soft surficial sediments (silt and unconsolidated clay) they will not meet most of the objectives of this project. However, for completeness, descriptions of selected gravity corers are given in Volume II.

5.3.2 Vibrocorers

Vibratory underwater samplers were originally developed for geological identification and mineral exploration rather than the determination of soil properties for engineering purposes. Vibratory drills are designed such that the direction of oscillation or vibration is limited to the direction of drilling. Vibrators are primarily of two types: (a) combinations of eccentric weights in pairs, which are driven in opposite directions such that their forces add in the vertical direction and cancel in the horizontal direction; (b) vibrating pistons (or hammers), which produce vibrations in only one direction. These systems are predominantly powered by electricity from a ship's generator, although some pneumatic models are also available for shallow water. Vibrocorers work on the principle that at appropriate frequencies of vibration, the sediment adjacent to the sample tube becomes thixotropic and acts as a lubricant aiding penetration of the corer. Presumably, each grain size and type of sediment has an optimum frequency yet most vibrocorers operate at a fixed frequency.

Vibrocorers are extensively used for sampling the upper 5 to 10 meters of the sediment layer. A number of models of various lengths (3, 6, and 12 metres) are available. Usually samples for subsequent laboratory analysis are recovered in a plastic liner within the central barrel of the unit. Liners are normally used only once, and this can add significantly to the unit cost per sample. Penetration depth and sample length recovered are very dependent upon soil type. In soft, cohesive material, such as lacustrine or estuarine sediments, sample recovery of 90 to 100 percent is common. In medium to coarse grain-sized material, recovery of 75 to 100 percent may be possible. There is generally less success in coring firm to stiff over-consolidated clays, glacial silts and gravels with little or no sand (Tirey 1972, Meisburger and Williams 1981). Poor penetration and refusal occur if obstructions are encountered or when attempting to sample dense overconsolidated material.

In recent years, work has been undertaken by a number of companies aimed at improving penetration in dense or hard soils and reducing sample disturbance. The techniques used include water jetting, vibro-rotary combination and vibro-impact drilling.

The vibrocorer is capable, when effectively deployed, of sampling up to 20 sites during a 12-hour working day.

5.3.3 Rotary Corers

Rotary drills of various types have been extensively used for many years on land, particularly for drilling of bedrock. The following description of the rotary drilling method is largely based on Lowe and Zacheo (1975).

> "In the rotary drilling method, the hole is advanced by rotating a drill string consisting of a series of hollow drill rods to the bottom of which is attached either a cutting bit or a core barrel with a coring bit. As the rods with the bit or barrel are rotated, a downward pressure is applied to the drill string to obtain penetration, and drilling fluid under pressure is introduced into the bottom of the hole through the hollow drill rods and passages in the bit or barrel. The drilling fluid serves the dual function of cooling the bit as it enters the hole and removing the cuttings from the bottom of the hole as it returns to the surface in the annular space between the drill rods and the walls of the hole. In an uncased hole, it also serves to support the walls of the hole.
>
> The procedure described above is referred to as straight rotary drilling. A second method of rotary drilling commonly used is referred to as reverse rotary or reverse circulation drilling. The difference in the two methods is primarily in the circulation of the drilling fluid to remove the cuttings and in the equipment used; the reverse rotary also is limited to use with noncoring bits. In the reverse rotary method, as the rods are rotated, the drilling fluid is introduced under gravity into the annular space between the drill rods and the walls of the hole. Alternatively, if double wall drillrods are used, the fluid is pumped down the annulus between the two walls. The fluid, laden with cuttings from the bottom of the hole, returns to the surface via the hollow drill rods. The return flow is accomplished by (a) application of a head at the top of the annulus relative to the discharge end of the drill rods; (b) application of suction on the drill rods; (c) introduction into the drill rods of a supply of air which mixes with the slurry and causes it to be removed by air lift. When compared to straight rotary drilling, this method has the dual advantage of (1) minimization of disturbance to the walls of the hole owing to the higher head in the hole and more outward seepage pressure on the hole walls; and (2) more rapid and efficient removal of cuttings from the hole since the area of the drill rods is less than the annulus thereby giving higher upward velocity."

Although rotary drilling methods have been used on land in some circumstances to obtain relatively undisturbed core samples of soil, more commonly soils are sampled by means of push-in or drive-in sample tubes, and rotary drilling is used to extend the borehole depth between sample locations. Where rotary drilling is used to obtain soil cores, face discharge, rather than side discharge cutting bits are normally used to minimize erosion of the core by the drilling fluid. The drilling fluid may be air, water or drilling mud.

A number of the rotary drillrigs originally developed for land use have been used offshore from a barge or ship, using straight rotary or reverse circulation techniques. In such applications, because the drill rods and casing form a rigid connection between the seabed and the surface vessel, a problem arises when heave or lateral movement of the vessel becomes significant. A heave compensation system may be used to minimize this problem.

Another approach to minimize weather dependency has been the development of remotely controlled, seafloor mounted rotary drilling platforms utilizing flexible connections to the surface vessel. Several of the systems evaluated for this project fall into this category. To minimize equipment weight and power requirements, some of these systems use a relatively small diameter (c.a. 25 mm) corebarrel. These systems have proved effective in recovering cores from exposed, unfractured bedrock. Fractured rock pieces, however, often cause the core barrel to jam and overlying sediments containing stones can also cause plugging of the core barrel. Small diameter rotary core drills are generally not suitable for sampling gravels containing particles larger than the core diameter.

Reverse circulation drilling methods can be used with larger core diameter, remotely operated, rotary drilling systems to deliver a continuous disturbed sediment sample to the surface vessel via a flexible hose.

There appears to be little published data on the performance of remotely operated rotary drilling systems in sampling placer or placer-like deposits.

5.3.4 Percussive Drill (Hammer Drill)

The Becker Hammer Drill utilizes a diesel pile hammer to drive a double-walled casing into the ground while, at the same time, air and/or water under pressure is delivered to the bottom of the hole through the annular space between the inner and outer walls of the casing. A special toothed bit at the base of the casing breaks the material being penetrated into small pieces. These pieces are removed by the air or water which returns to the surface via the inner casing.

The equipment was originally developed as a land-based system and its use has since been extended to overwater applications.

5.3.5 Air Lift Systems

This type of equipment is widely used to prospect for marine sand and gravel deposits. A jetting pipe is suspended by a cable and lowered to the seabed. Separate flexible hoses supply air and water under pressure to near the base of the jetting pipe and the soil cuttings travel up the jetting pipe and then by another flexible hose to the surface vessel. Samples are taken at appropriate depth intervals from the soil/air/water mixture returned to the surface. These samples are allowed to stand so that the solids settle and surplus water can then be decanted off.

With some systems, a pneumatic hammer is mounted on the jetting pipe to facilitate penetration of dense or cemented materials. Air lift systems are capable of providing a disturbed bulk sample comprising the complete sediment column to a depth of 10 or 15 m and, from this, selected samples may be extracted at specified depth intervals.

5.4 DRILLING/SAMPLING SYSTEMS ASSESSED

Details of the various drilling/sampling systems assessed as part of this study are given in Volume II of this report. A total of 13 gravity piston corers, 20 vibratory corers, 19 rotary corers, 2 jet airlift systems and 1 hammer drill were included in this assessment, as summarized in Tables 4.1 to 4.5 (Volume II).

The development of specialized equipment for sampling of marine sediments is a relatively new field. The majority of the systems evaluated have been developed in the last 12 years. Modifications to existing equipment and introduction of new techniques to improve the ability to collect marine sediment samples is an ongoing process. Factual performance data on the majority of the systems evaluated is limited. This is partly due to the high cost and logistics problems associated with mounting an extensive field test program in a variety of sediment types. Also, companies currently involved in offshore placer exploration tend to consider equipment performance data of commercial value and are thus reluctant to provide these data freely. As a result, the evaluation of various systems carried out for this project has been based mainly on the manufacturer's literature and is, of necessity, somewhat subjective.

5.5 SYSTEMS REJECTED AFTER PRELIMINARY ASSESSMENT

After preliminary assessment, the following systems were not considered suitable in the context of this project and detailed evaluation of these systems was not undertaken:

Gravity/Piston Corers

These systems are not able to meet the performance criteria, see discussion in Section 5.3.1.

University of Rhode Island - Vibrocorer

Designed for maximum penetration of 2 metres.

Dutch Geological Survey - Roflush II

System still under development. Judging from proposed specification, this equipment may warrant further assessment when development is complete.

Koken Drill

Bedrock sampling only. Very large system (27 m by 5.5 m) and difficult to handle from any size vessel.

Texas A&M - SeaCore 50

Only conceptually designed, never built.

French Petroleum Institute - ECSM 2

Bedrock sampling only, maximum core length is 1 metre and equipment has received limited usage.

Geological Survey of Japan - MD-300PT

Bedrock sampling only, maximum core length is 1 metre.

Woods Hole Rock Drill

Bedrock sampling only, maximum core length is 1 metre and core diameter is 19 mm.

Hyco Slack - Line Corer

Bedrock sampling only, system developed in the 1970's and has since been abandoned. Core length/diameter is 3 m/41 mm.

Terrasearch Limited - Seabed Sampler

System developed 1974-75 and has received limited usage. Very large system, impossible to handle from a small vessel.

Harrison Hard Rock Corer

Bedrock sampling only, and core length/diameter is 0.25 m/10 mm.

Naval Engineering Laboratory - Remote Controlled Seafloor Incremental Corer

System failed most tests and its development was abandoned.

Mobil Auger and Research Limited - DGD - 2000

Large system requires shipboard derrick and moonpool. Has been used successfully in the Beaufort Sea. However, designer does not consider that the drill is suitable for use in long high swells or from a relatively small vessel in exposed ocean conditions.

Mackereth - Portable Core Sampler

Capable of penetrating soft sediments only.

University of Miami - Portable Vibrocorer

Maximum water depth 18 m. Samples only unconsolidated sediments. Requires diver support beyond 10 m water depth.

Marex Vibrocorer

Samples fine sand and clay only. Maximum core length 3.9 m.

Atlas Copco and Wimpey Maricor Sample

Very large and complex system developed in 1970's has received limited use. Requires large vessel and experienced crew to operate.

NORDCO - Electric Rock Core Drill

Small diameter core; system not designed to sample sediment.

Lockheed Corer

Minimal penetration, bedrock only.

Comments on the systems which were assessed in more detail are included in Section 5.6.

5.6 SYSTEMS SUBJECTED TO MORE DETAILED EVALUATION

5.6.1 Systems Included

A comparison of the key features of the sampling systems which, after preliminary assessment, were selected as warranting more detailed study, is presented in Table 5.1 (in back pocket).

Examination of the available data on these systems has clearly demonstrated that no single system can satisfy all of the project objectives. As outlined in Section 5.0, the objectives of minimizing equipment cost and of selecting equipment which is suitable for use by relatively unskilled personnel from a "small fishing vessel" tend to conflict with the equipment performance objectives concerning use in a harsh, offshore environment; desired sub-seabed exploration depth; and minimum acceptable sample size. In view of this, and following further discussion with the scientific authority of the project, it was decided to evaluate the various drilling/sampling systems under the following categories.

Category 1

Equipment considered basically suitable for operation from a "small fishing vessel" and capable of sampling to a depth of 5 to 10 m below the seabed and which meets as many of the other criteria outlined in Section 5.2 as possible.

Category 2

Equipment which is generally considered capable of meeting the project objectives concerning sample quantity and quality, penetration depth, and sediment types which can be sampled. This equipment may not be suitable for operation from a "small fishing vessel" and may not meet the project objectives concerning cost, operator skills, minimal requirement for ancillary support services, and ability to sample the bedrock/overburden interface.

It may be practical to utilize Category 1 systems from a relatively small vessel for carrying out preliminary or reconnaissance surveys. Subsequently, more detailed investigations could be carried out using Category 2 systems on larger vessels, in areas selected based on the results of the reconnaissance surveys.

5.6.2 Systems Recommended for Field Trials

By evaluating the available data on each of the systems included in Table 5.1, in relation to the project objectives, the following systems have been selected and are recommended for field trials, and comparative performance evaluation, under Phase III of the project.

Category 1 Systems

a) Primary System

Alluvial Mining Vibro-Impact Corer (VIC)

b) Possible Alternatives to the Primary System

Geodoff I (Mark 2)
Aimers McLean/BGS Vibrocorer
Alpine Vibracore
Geomarex P4 Vibrocorer
Haamer Vibrocorer

Category 2 Systems

Alluvial Mining AMdril

It is recommended that comparative trials should be carried out with the primary system in each category, and one or more of the alternative systems in Category 1, depending on the level of funding available for Phase III of the project, and provided that suitable lease arrangements for the equipment can be made (see Section 6.2.1).

Comments on each of the above systems follow.

Alluvial Mining Vibro-Impact Corer (VIC)

The primary candidate system for Category 1 is a relatively recent development, the Vibro-Impact Corer, developed by Alluvial Mining Limited in conjunction with the Department of Engineering, Aberdeen University, and now marketed by Alluvial Mining (Rodger et al. 1986).

This equipment, which is available in 3, 4, 6, 8, and 10 m versions, employs a vibro-impact converter unit coupled to a conventional pure vibration corer to generate vibro-impact motion. The system is controlled remotely from a ship through a flexible electric power line connected to a variable frequency supply.

Geological considerations indicate that in facies types 1 and 2 (see Table 3.1 and Figure 3.1), there is good potential for placer deposits associated with lag gravels in the upper 5 to 10 metres of surficial sediment. The Vibro-Impact corer is considered generally capable of samping this type of material to the required depth. Although the equipment is available in up to 10 metre sampling depth capacity, operation from "a small fishing vessel" may have to be limited to the 6 to 8 metre version (Alluvial Mining, 1986). However, there is little potential of any of the Category 1 systems sampling below 1 metre in the over-consolidated material of facies type 3.

Figure 5.2 shows the vibro-impact machine, which consists of a vibrating mass with a percussive part (the striker) and a driving cap (the anvil) interconnected by springs. The percussive part delivers the impacts, and the springs transfer the vibrations to the driving cap. In loose soils the machine will provide vibration only, which reduces soil resistance enough to induce penetration. When the machine encounters materials with higher resistance to penetration, it automatically begins to impact to maintain penetration. The magnitude of the impacts produced is dictated by the effective coefficient of restitution which in turn depends on the soil resistance. The machine

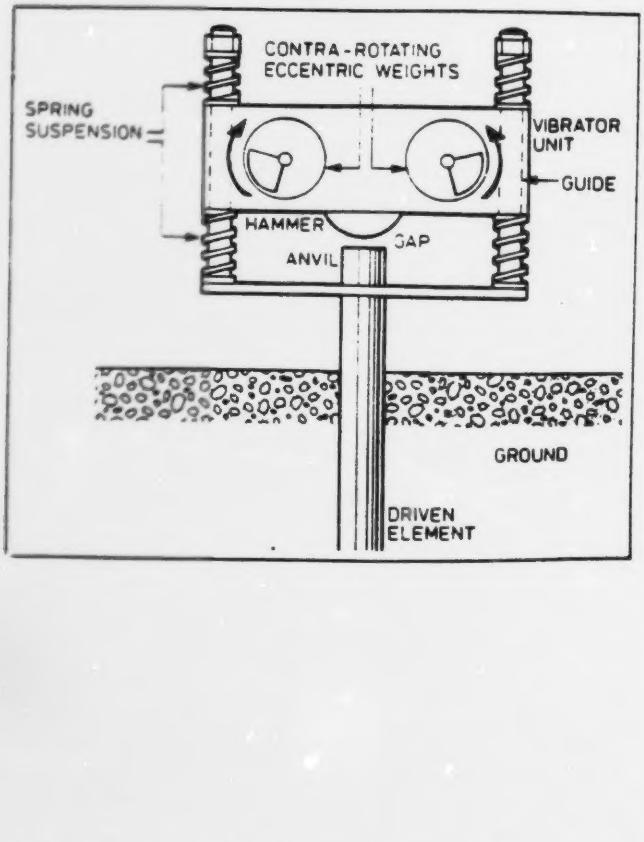

CONTRA-ROTATING ECCENTRIC WEIGHTS
SPRING SUSPENSION
VIBRATOR UNIT
GUIDE
HAMMER
GAP
ANVIL
GROUND
DRIVEN ELEMENT

FIGURE 5.2 Alluvial Mining Vibro-Impact Corer (VIC) Mechanism

therefore applies only sufficient energy to maintain penetration, thus minimizing the disturbance induced in the recovered soil sample. In addition, because the machine adjusts itself to cope with different soil conditions, it can be used to provide penetrometer-type data while coring. A shipboard microcomputer-based system can be used to produce soil resistance profiles simultaneously with coring operations.

During its first year of commercial operation the corer has seen widespread use. In operations in the southern North Sea, for example, the VIC has proved highly successful in retrieving continuous cores up to 2 m long in stiff clay during difficult weather and current conditions. Average core recovery was 90 percent. On another offshore site, the VIC achieved coring rates of over 65 m in a 12-hour period, with 10 or more locations being cored in any one day. (Rodger et al. 1986)

Geodoff I (Mark 2)

Geodoff I (Mark 2) (see Figure 5.3) is a remotely controlled vibrocorer designed to take a 67 to 150 mm diameter core sample to a maximum depth of about 7 m into the seabed. The maximum operating water depth is 200 m.

Subsequent development has added the options of core drilling of bedrock and also of sampling sediments by air-lift counterflush methods to a maximum depth of about 15 m below the seabed. When operating in the counterflush mode, the 150 mm diameter corebarrel is vibrated into the seabed and a continuous disturbed soil sample is returned to the surface via a flexible hose.

It is understood that a Geodoff sampler has been used off Australia for placer exploration (Seacore 1986, Balzer 1986) but there is some uncertainity whether this was the Geodoff I (Mark 2) or the Geodoff II system. As yet it has not been possible to obtain performance data for this work, other than the brief details quoted by Balzer.

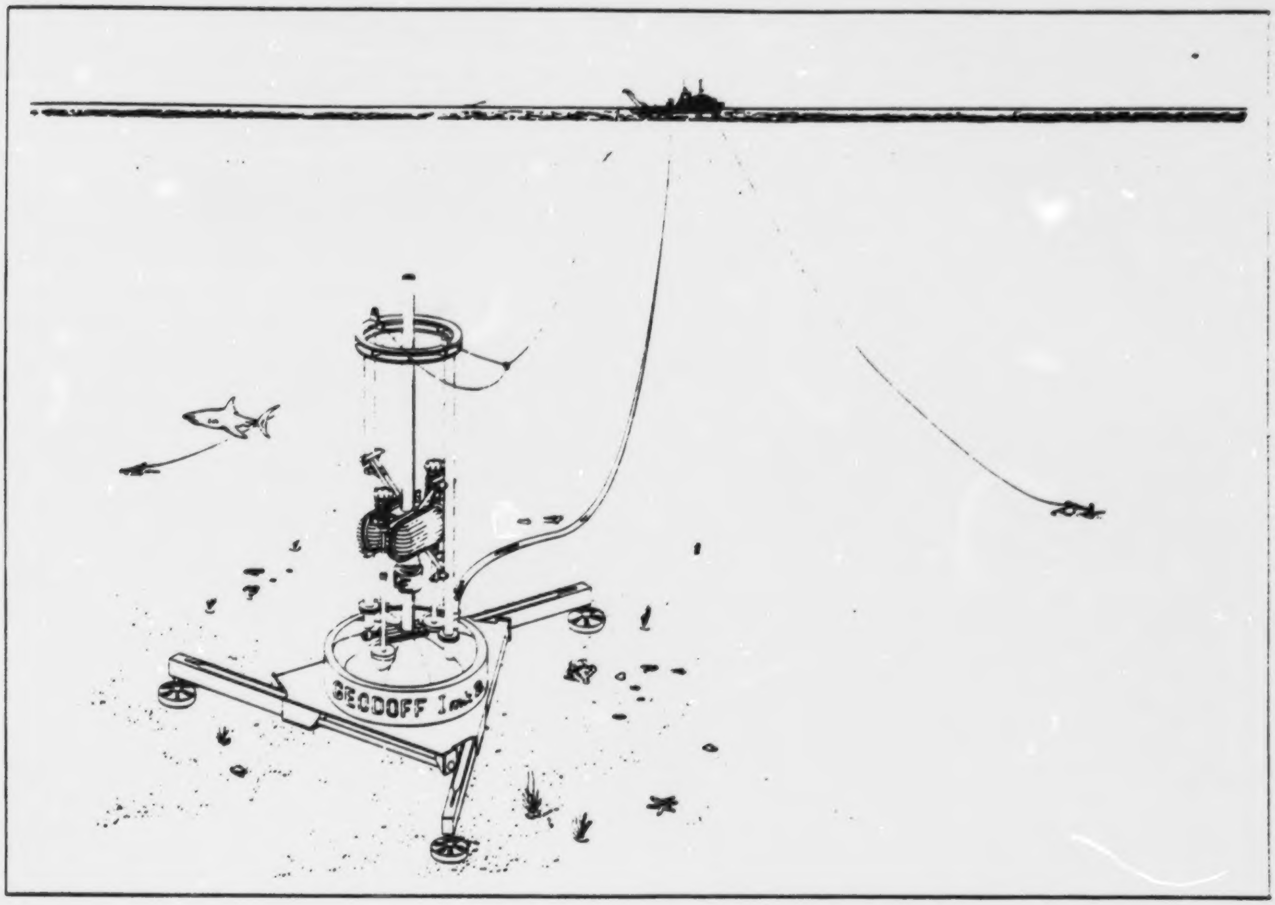

GEODOFF I mk 2

FIGURE 5.3 GEODOFF I (MARK 2) Vibrocorer

The system is considered to have good potential in the context of this project and it is recommended that field trials should be carried out in Phase III.

Aimers McLean/BGS Vibrocorer (Figure 5.4)

The manufacturer of this equipment is now out of business but systems may be available on a lease basis from existing owners. This is a remotely operated, electrically powered vibrocorer similar in configuration to the basic vibrocorers currently being marketed by Alluvial Mining Limited and others. The system is recommended on the basis of equipment reliability and a generally good performance record. It is possible that a modified 6 metre system may be available on a lease basis to Phase III of the project from the Atlantic Geoscience Centre (AGC) at Bedford Institute of Oceanography. Modifications made by AGC consist of an improved electronic package and the addition of a core barrel retraction system. Penetration of this equipment in dense material is generally limited to approximately 1 metre, and it is anticipated that the overall performance of this system in the context of this project will not match that of the Alluvial Mining Vibro-Impact Corer. Nevertheless, it is recommended that comparative field trials should be carried out with this equipment and this can probably be done at a modest cost increase.

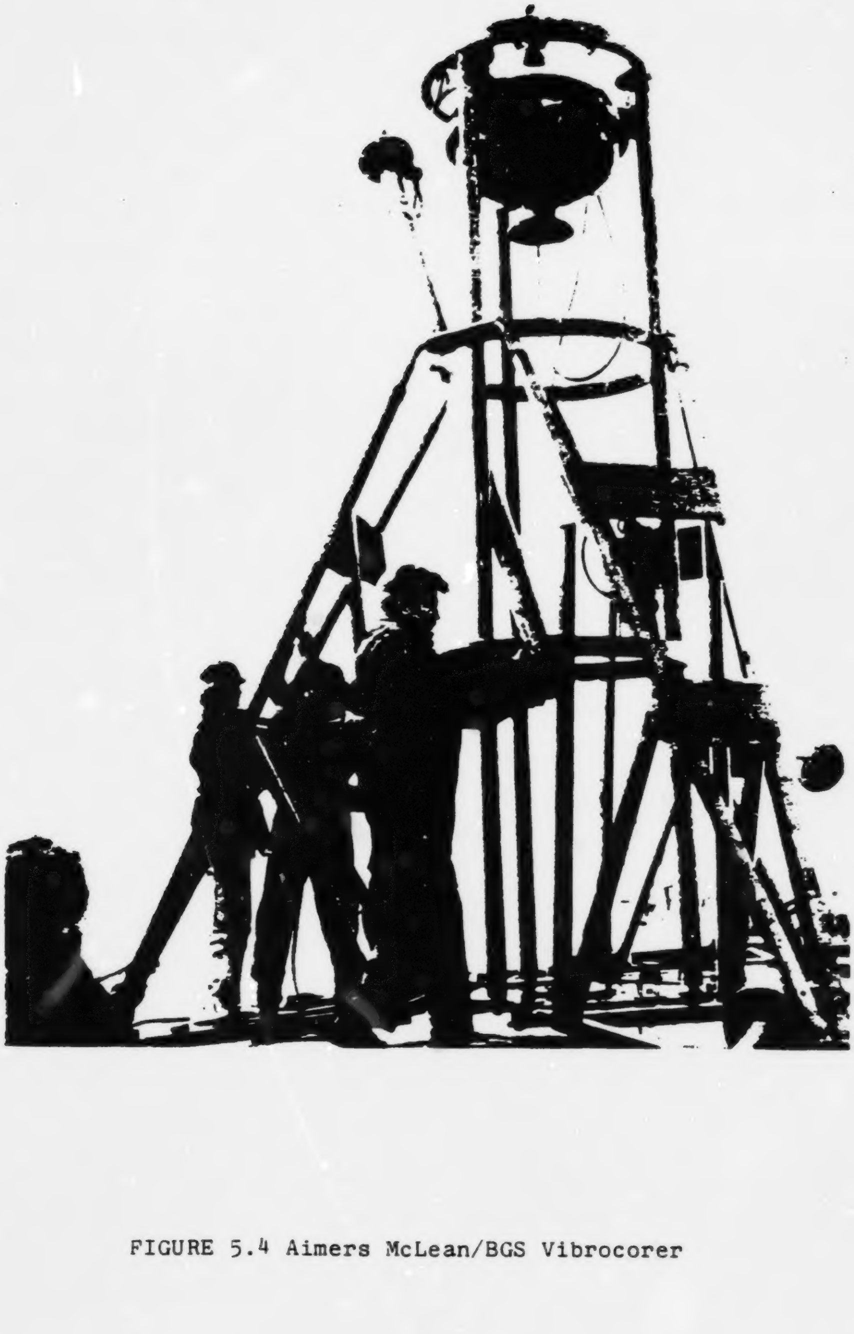


FIGURE 5.4 Aimers McLean/BGS Vibrocorer

Alpine Vibracore (Figure 5.5)

This is the oldest system on the market, and it has a proven record of successful operational experience. The pneumatic impacting piston requires a shipboard air compressor. Water jetting is also available to increase the depth of penetration achieved. Performance of this system is believed to be generally better than that of the Aimers McLean system. It is reported that this equipment can sample soils ranging from stiff clays to sand and gravels; however, less success has been encountered in coring glacial tills and gravels with little or no sand. The major disadvantage of the system is the lack of a built-in core barrel retraction system. Because of this, the shipboard winch is used to retract the corebarrel prior to lifting the sampler from the seabed. Depending on penetration depth and sediment type, a normal retraction force of 10 tonnes is necessary and during difficult conditions up to 30 tonnes may be required.

The manufacturer claims that the Alpine Vibracore is capable of taking an 89 mm diameter core within a plastic liner tube from most marine materials which can be classified as "unconsolidated sediments."

The system has been used successfully for over 18 years by the U.S. Army Corps of Engineers to obtain over 1,600 cores mainly on U.S. Inner Continental Shelf areas (Meisburger and Williams 1981). Alpine Ocean Seismic Survey Inc. has many years of experience in using the Vibracore searching for offshore marine deposits containing gold, tin, phosphate and sand and gravel aggregates, in coastal areas such as Cornwall, New Zealand, North Carolina and other areas of the eastern U.S. (Alpine 1986).

Different versions of the equipment designed to take cores 6, 9, or 12 m in length are available. Operations from a "small fishing vessel may have to be limited to the 6 or 9 m versions to minimize possible handling problems.

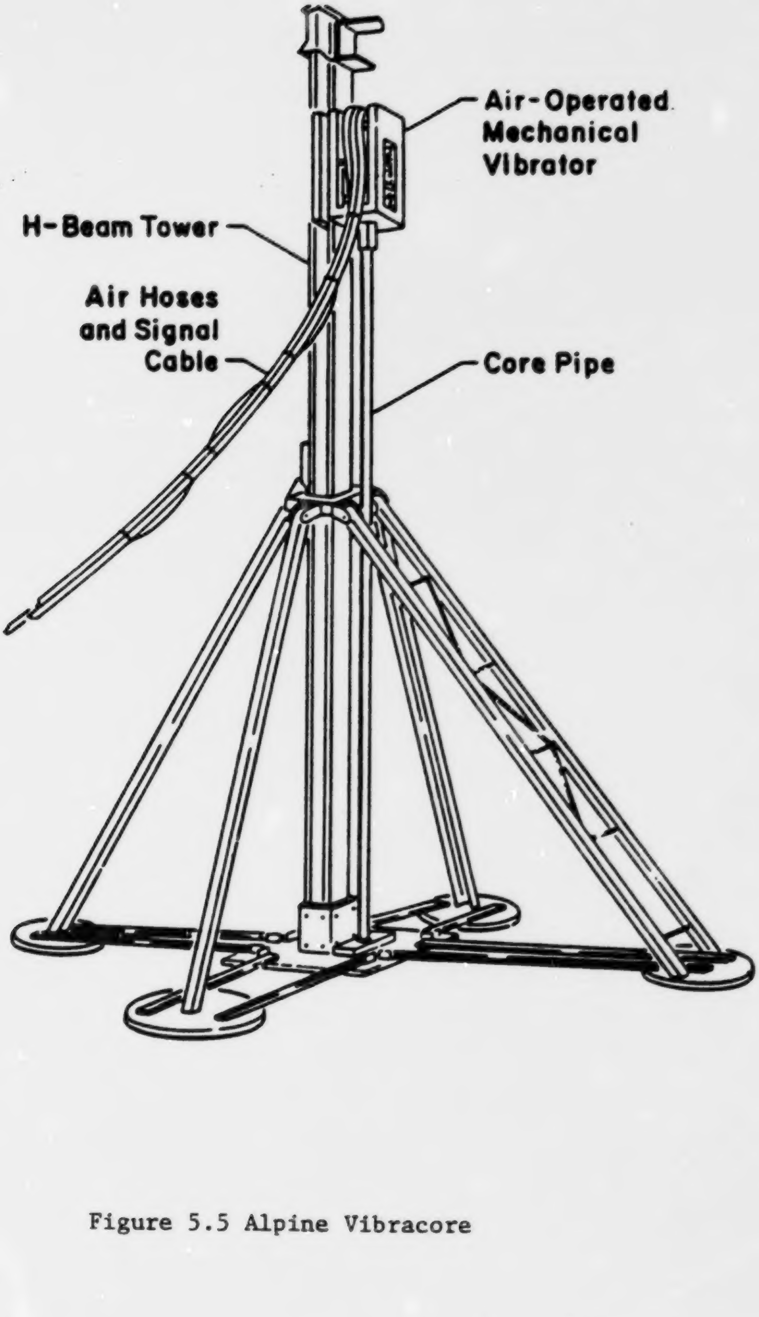

Air-Operated Mechanical Vibrator
H-Beam Tower
Air Hoses and Signal Cable
Core Pipe

Figure 5.5 Alpine Vibracore

Geomarex P4 and Haamer Vibrocorers (Figures 5.6 and 5.7)

These systems are both considered to be well suited to deployment from a "small fishing vessel" because of the following factors:

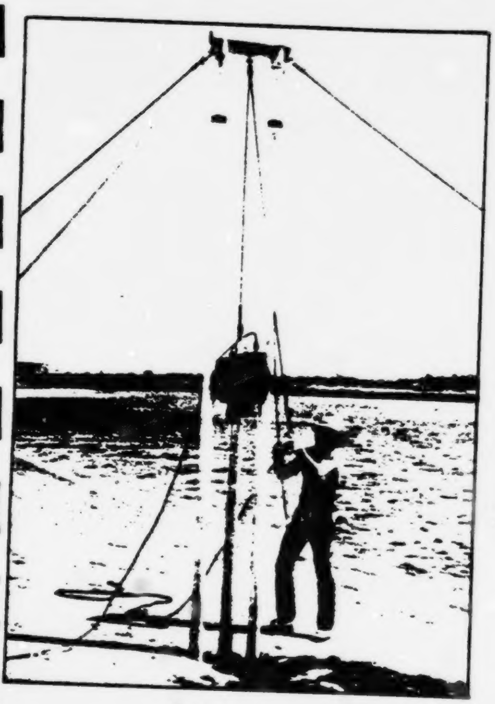
- geometric configuration, size and weight,
- shipboard handling, and
- ease of operation.

Both systems use water jetting near the tip of the cutting shoe to improve penetration, and a buoyancy package to align the core barrel with the base plate and to provide additional downward reaction force during operation. The major disadvantage is that these systems have not yet proven the ability to sample the relatively coarse sediment types expected to be encountered in places on the Scotian Shelf. A comparison of these systems based solely on the manufacturer's claims appears to favour the Geomarex vibrocorer over the Haamer in the context of this project. For example:

	Geomarex	Haamer	
	P4	6 m	12 m
Core Diameter, mm	100	57	81
Weight, kg	275	480	1,000
Cost, $Cdn.	40,000	47,000	

Geomarex have reported that during a placer evaluation program with the P4 system off New Zealand in 1982, some difficulty was experienced in obtaining cores more than 3 m in length because of the very fine, compacted nature of the sediments. After switching from plastic lined steel core barrels to linerless aluminum barrels, improved sample recovery was achieved (Geomarex 1986).

As yet, we have not been able to obtain any performance records for the Haamer Vibrocorer subsequent to the work reported in 1976 (Jonasson 1976).



Model P1

Model P4

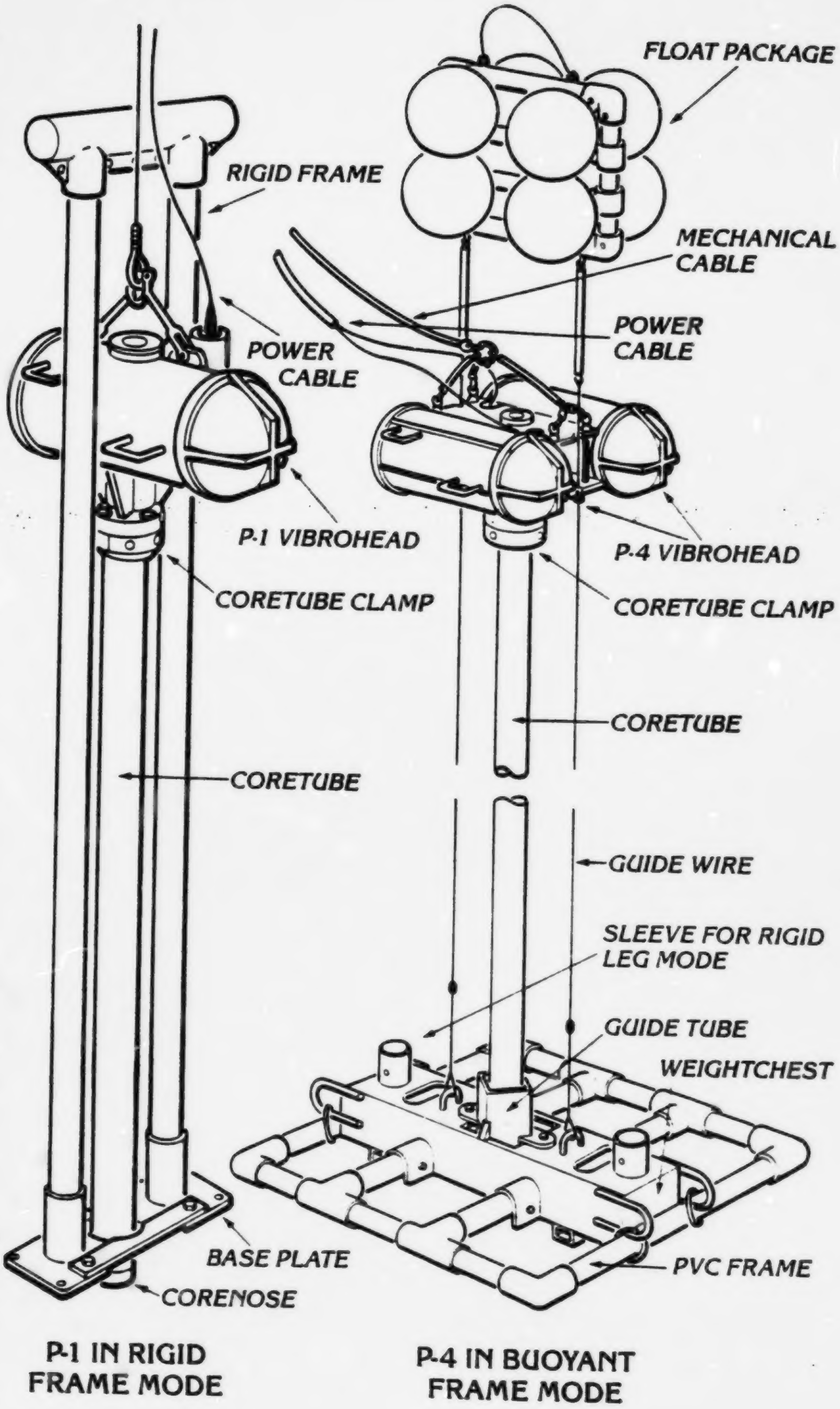
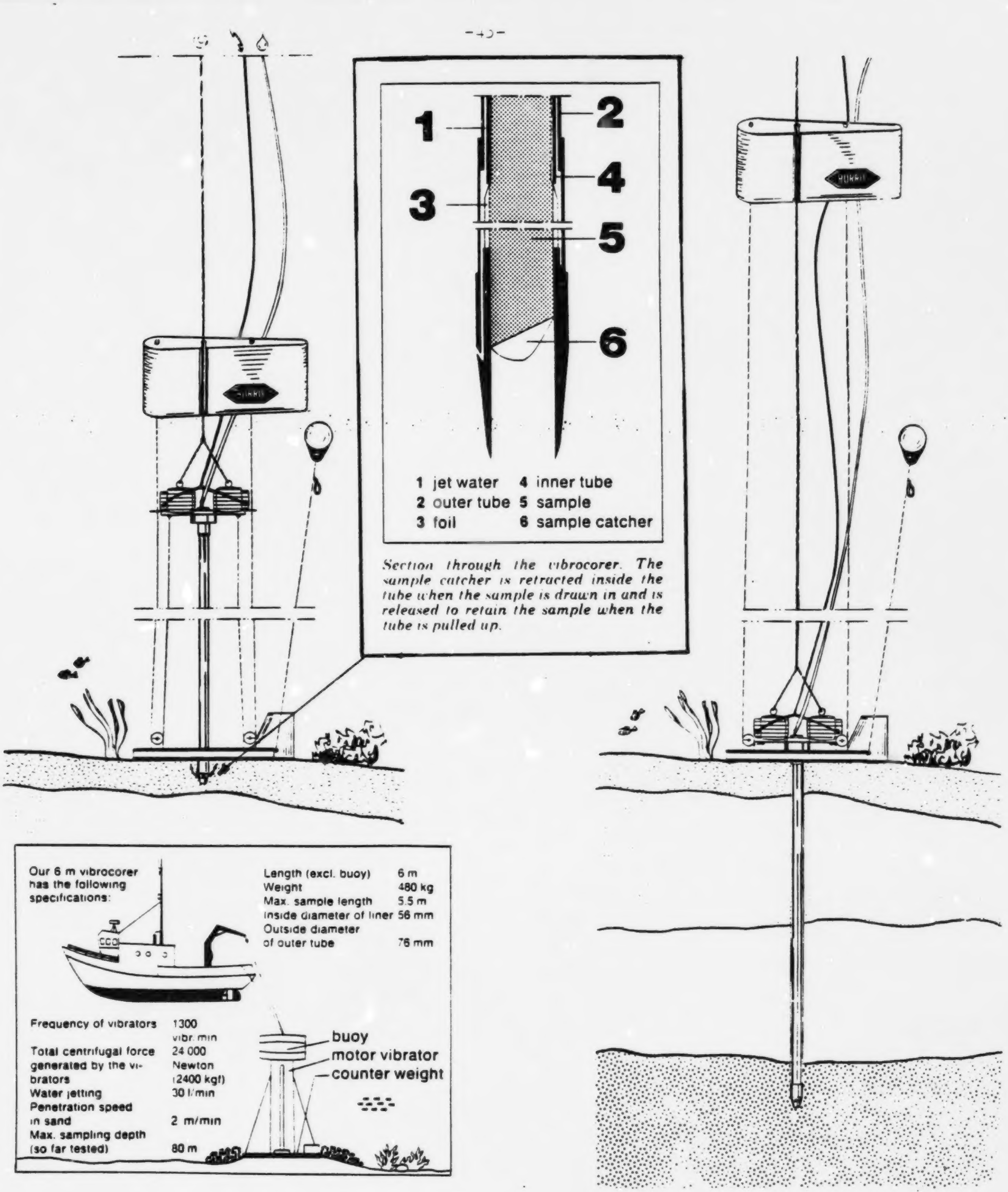

FLOAT PACKAGE
RIGID FRAME
MECHANICAL CABLE
POWER CABLE
POWER CABLE
P-1 VIBROHEAD
P-4 VIBROHEAD
CORETUBE CLAMP
CORETUBE CLAMP
CORETUBE
CORETUBE
GUIDE WIRE
SLEEVE FOR RIGID LEG MODE
GUIDE TUBE
WEIGHTCHEST
BASE PLATE
PVC FRAME
CORENOSE
P-1 IN RIGID FRAME MODE
P-4 IN BUOYANT FRAME MODE

Figure 5.6

Geomarex Vibrocorer

Model P1 and P4


1
2
3
4
5
6
1 jet water
2 outer tube
3 foil
4 inner tube
5 sample
6 sample catcher
buoy
motor vibrator
counter weight

Section through the vibrocorer. The sample catcher is retracted inside the tube when the sample is drawn in and is released to retain the sample when the tube is pulled up.

Our 6 m vibrocorer has the following specifications:

Length (excl. buoy)	6 m
Weight	480 kg
Max. sample length	5.5 m
Inside diameter of liner	56 mm
Outside diameter of outer tube	76 mm

Frequency of vibrators	1300 vibr. min
Total centrifugal force generated by the vibrators	24 000 Newton (2400 kgf)
Water jetting	30 l/min
Penetration speed in sand	2 m/min
Max. sampling depth (so far tested)	80 m

Figure 5.7

Haamer Vibrocorer

Alluvial Mining AMdril (Figure 5.8)

The Category 2 system recommended for field trials is the AMdril - an airlift system developed by Alluvial Mining Limited primarily for evaluating submerged mineral-bearing alluvial deposits.

The system can operate in water depths up to 150 m and can penetrate the seabed up to 15 m. The unit is a combined water jetting/continuous sampling/airlift system, with a pneumatic hammer to assist in penetration of dense soils. The standard coring tube is 150 mm diameter, but 250 mm and 450 mm versions are also available. Water jets located around the periphery of the corebarrel breakup and entrain the sample into the suction orifice. Air is injected above the orifice to lift the soil/water slurry to the surface through a flexible hose to a sample collector/splitter on the ship's deck. The pneumatic hammer used to aid in penetration of difficult (i.e. dense or cemented) materials is located in a watertight housing on top of the drill head. Exhaust air is vented to the surface.

The drill is usually operated from a sea-going vessel of about 500-600 tonnes. The vessel normally requires at least a single-point bow mooring system, and a heave compensation system with a minimum vertical travel of 4 m to support the drill pipe. At least one 20 tonne winch is required for lowering and raising of the drillpipe. Other ancillary shipboard equipment required includes a 17 cu m/min air compressor and a 1,150 litre/min high pressure water pump (Alluvial Mining 1986).

The AMdril system has been used extensively in the U.K., Australia and elsewhere for exploration of offshore sand and gravel, and gold, rutile and tin-bearing placer deposits with apparent success. For example, the system was used by Alluvial Mining off the eastern coast of Australia and Tasmainia in 1967-8 to evaluate potential offshore gold, rutile and tin deposits in water depths of 20 to 50 m. During this program, the system sampled silts, clays and hard, compact sands. Miles (1985) reports that the system has been able to complete 20 holes, each over 10 m in depth in a 12-hour working day.

AMdril has been used extensively in the U.K. for evaluation of offshore sand and gravel deposits and seems to perform well in gravelly material.

The physical collection of selected sample material is achieved by a pneumatically operated valve and surge tower located at the sample collection station. Samples are normally collected in mobile containers of 140 litre (5 cubic feet) capacity at a frequency determined by the information required from the borehole. A 1 metre depth sample frequency is often used. More precise depth definition may be difficult because of the type of sample obtained (i.e. a continuous stream of soil-water-air mixture).

In the present context the possibility of settling-out of gold particles from the soil/water slurry at the base of the sampling tube is an undesirable feature. However, this factor does not appear to have precluded use to date of the AMdril (and other airlift systems such as the Ocean Science and Engineering Jet Airlift and Becker Hammer Drill) for exploration of offshore gold-bearing placer deposits. As discussed in Section 6.0, it is recommended that part of the work to be carried in Phase III of this project should be aimed at determining whether samples of gold-bearing placers obtained by jet airlift or reverse circulation (i.e. counterflush) systems are sufficiently representative of the in-situ material to permit an accurate economic evaluation. Since the AMdril sampling tube can be partially driven into the seabed by the pneumatic hammmer, it is considered preferable in this regard to the Ocean Science and Engineering system.

AMdril

Table 2: Analysis of drilling results achieved by 50-ft. AMdril in 160 ft. of water during winter months over a two week period

Day	Footage	Depth Max.	Depth Min.	Material	Average sea state (Feet)	Estimated wind speed (Beaufort)	Holes
1	19	12	2	Sand/Gravel	4-10	5-7	3
2	Nil	Nil	Nil	Nil	10-15	7-8	Nil
3	158	20	1	Sand/Gravel	5-12	2-4	15
4	43	17	5	–	6-12	3-5	5
5	97	21	1	–	3-4	3-4	10
6	108	18	1	–	3-4	1-2	10
7	48	14	2	–	3	3	6
8	50	18	1	–	3-4	1-3	7
9	90	17	3	–	1-2	2	10
10	25	7	2	–	1-6	2-4	8
11	147	33	1	–	3-4	4	11
12	Nil	Nil	Nil	Nil	6-10	6-7	Nil
13	Nil	Nil	Nil	Nil	6-10	6-7	Nil
14	103	38	30	Sand/Gravel	3-5	3-4	3

Specification

Barrel sizes:
150mm, 250mm, 450mm
Seabed penetration
6m, 10m, 12m, 15m
Compressor 600 cfm
Water pump 250 gpm
Winch 20 tons
Sample settling tubs
Swell compensation
Sample splitter
Control console
Depth/time penetration recorder
Coaster-type vessel
One-point mooring

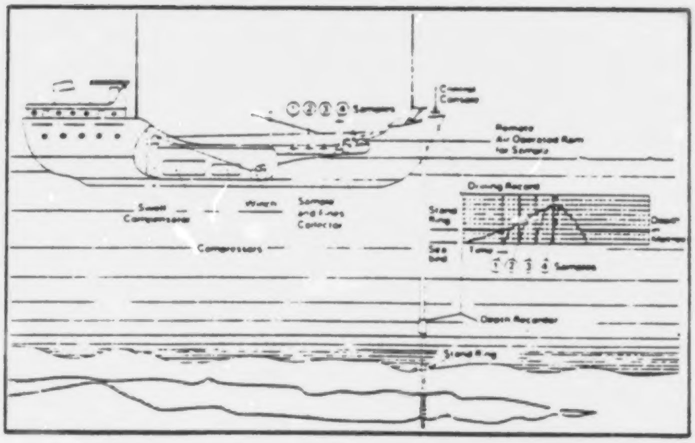

Control Console
① ② ③ ④ Samples
Remote Air Operated Ram for Sample
Drilling Record
Swell Compensator
Winch
Sample and Fines Collector
Compressors
Stand Ring
Sea bed
Time
Depth
Metres
1 2 3 4 Samples
Depth Recorder
Stand Ring

Figure 5.8

Alluvial Mining AMdril

5.6.3 Comments on Systems Not Selected for Comparative Field Trials

In Section 5.6.2, an attempt has been made to select a short-list of drilling/sampling systems which are most nearly able to meet the revised performance objectives of the present project, as defined in Section 5.2. Comparative performance trials with some or all of these systems is proposed in Phase III (see Section 6.0). Exclusion of any particular system from this short-list does not necessarily imply that the equipment is considered unsuitable for sampling of placer deposits.

Comments are given below on a number of the systems included in Table 5.1 which were not selected at this time for further evaluation.

Geomarex Hummingdrill and Wink Vibra-Corer

These are both very light, portable, high frequency vibratory drills principally developed for overland prospecting. The two units appear to be similar in many respects.

These systems appear to have the advantage of low cost and simplicity of operation. Disadvantages are the low power availability, lack of any form of motion compensation, and particularly for the Wink Vibra-corer, the relatively small sample size produced. These systems are not considered suitable for sampling sediments containing any significant amount of medium to coarse gravel.

It is known that the Wink system has been used previously for exploration of gold bearing placer deposits off Nova Scotia (Mer Resources 1986, Dimock 1986)). It is understood that the limiting wave height for safe operation of the system in that program was about 1 metre. Moreover, in order to produce sufficient sample for analysis, two holes were drilled at each location in the 1985 program and it was proposed to drill three holes at each location in subsequent work (Mer Resources 1986).

Because of these factors, the vibrocorer systems included in Section 5.6.2 of this report are considered to be more appropriate in the present context than the Geomarex Hummingdrill or the Wink Vibra-Corer Systems.

Horton Vibrocorer

The manufacturer of this equipment is now out of business. Although the system is relatively tolerant of vessel heave, lateral motion of the support ship or barge must be kept to a minimum, and this generally requires a four-point mooring system. Dimock (1986) reports that in an exploration program off Tasmania in 1966 in which this system was used, 27 percent of the potential drilling time was lost due to adverse sea conditions.

U.S. Geological Survey Portable Hydraulic Vibrocorer

This system requires the use of scuba divers for underwater assembly and disassembly of the various components. The equipment is not commercially available.

Seabed Rokleng Air Hammer

This system is still under development and is not part of the generally advertised equipment of Seabed b.v. The air hammer method is not presently favored by the manufacturer and a hydraulic hammer is being developed (Seabed 1986).

Seabed b.v. (SVC 500E and 500 ETR) and BRGM V4S8 Vibrocorers

This equipment is considered comparable to the various vibrocorer units included in Section 5.6.2 as possible alternatives to the primary system. The Seabed and BRGM equipment does not appear to have any significant advantage over those systems.

Conrad - Stork Drills

Although the Conrad - Stork series of surface operated drills have been used quite extensively for exploration of placer deposits, particularly in South East Asia, (Dimock 1986, Arkana 1986), it is believed that much of this work has been from barges or pontoons in relatively sheltered, nearshore locations.

Handling of the drillstring is often facilitated by using a 7 m high A-frame. This equipment is not considered suitable for operation in exposed offshore locations from a small fishing vessel. Furthermore, it does not appear to have any significant advantages over the Category 2 system included in Section 5.6.2.

C-CORE Geotechnical Corer

In view of the amount of further development work considered necessary (Christian 1984), this system is not recommended for field trials in Phase III.

However, the basic concept of using rotary drilling methods with a relatively large diameter triple tube core barrel, and using drilling mud as a flushing medium, deserves further consideration. Comments on this are included in Section 6.2.2.

Geodoff II

Geodoff II utilizes a series of twelve 4 m long core barrels which are drilled sequentially into the seabed to provide core samples to a maximum penetration depth of 48 m (Anonymous 1970). This system can also be used with counterflush drilling methods to return a continuous disturbed sample to the surface. Actual performance data for this system is sparse.

The system is relatively heavy (10 tonnes) and is not considered suitable for operation from a small fishing vessel in the context of the present project.

NORDCO Electric Auger Drill (SEADRILL II)

In its present configuration, this system incorporates a relatively complex computer-assisted control and monitoring system, and thus a skilled operator is essential. In addition, the present daily lease cost of SEADRILL II is of the order of $2,500 (Canadian) per day. Further development work on this system is planned for early 1987 to test a variety of sediment sampling techniques.

Primarily because of these factors, the system is not recommended for field trials in Phase III of this project. However, the basic concept of using a hollow stem, continuous flight auger to penetrate seafloor soils and to provide a convenient conductor casing for the deployment of a variety of sampling tools, is considered to have good potential in the present context. Further comments on this are included in Section 6.2.2.

Like the C-CORE drill, the unit has the potential to obtain core samples of the sediment/bedrock interface, where this is located within the depth capability of the system.

CREO Underwater Frame BSM 12

Available technical data is sparse. As yet, it has not been possible to obtain any performance data for this equipment.

Osiris - Cesco SEASAM

From a limited amount of available information (Circa 1981), this appears to be a versatile unit with good potential. The present status and availability of this equipment is not known. Further investigation may be warranted in the future, depending on the results of Phase III of the project.

Ocean Science and Engineering Jet Airlift System

The manufacturer of this equipment is now out of business. This system has the advantage that it can be operated from a smaller vessel than the AMdril system included in Section 5.6.2. Disadvantages of the OSE equipment include lack of a heave compensation system and thus increased weather dependency; increased tendency for caving of the borehole (and resultant oversampling) since the sample tube is not driven or vibrated into the seabed; and apparent tendency for denser particles to settle out of the suspended sediments prior to entry into the sample tube. Dimock (1986) reports that a correction factor of 300% has been used to modify gold assay results to correct for this last effect.

In view of all these factors, the AMdril system is considered preferable in the present context.

Becker Hammer Drill

This system, originally developed for on-land operations, has been used quite extensively for offshore mineral exploration (Dimock 1986, Becker 1986). The drill is designed to deliver a continuous, disturbed sample to the surface using reverse circulation (counterflush) methods. The basic elements of the system comprise an air compressor, a mud pump, a diesel pile hammer, a rotary drive unit, a hydraulic hoist, a casing puller, a mast, a cyclone for the collection of samples, and lengths of double wall steel casing (see Figure 5.9).

The system is relatively large and heavy (11.5 tonnes for drill unit) and for over water work a moonpool or "over-the-side" cantilevered work platform is required. Because of these factors the system is not considered suitable for operation from a small fishing vessel. For offshore work the equipment manufacturer recommends mounting the drill on a jack-up barge to provide a stable working platform and reduce weather dependency. However, this limits the maximum working water depth.

The major advantages of the system are the rapid penetration rate which can be achieved and its ability to penetrate material containing cobbles and/or boulders.

This system has not been recommended for field trials in Phase III of this project. Future consideration of this system may be appropriate following the completion of Phase III, particularly if the field trials indicate that placer deposits offshore Nova Scotia contain materials which cannot be penetrated and sampled by the AMdril system.

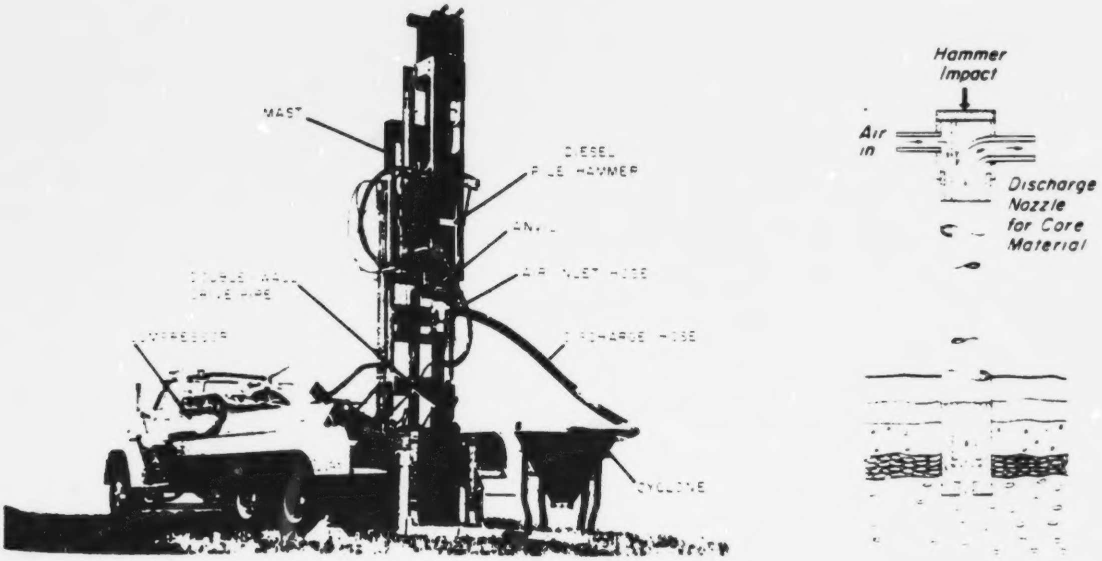

MAST
DIESEL PILE HAMMER
ANVIL
AIR INLET HOSE
DOUBLE WALL DRIVE PIPE
COMPRESSOR
DISCHARGE HOSE
CYCLONE
Hammer Impact
Air in
Discharge Nozzle for Core Material

Figure 5.9
Becker Hammer Drill

6.0 RECOMMENDATIONS FOR FURTHER WORK

6.1 ORIGINAL INTENTIONS FOR PHASE III

The Statement of Work for the present contract (Phases I and II of the project) indicated that the next stage (Phase III) would include the design of a prototype sample recovery system which may consist of two types of drilling/coring systems capable of being mounted onto a small fishing vessel or barge, and an onboard sample processing system to recover minerals from the drill cores. It was also intended that Phase III would include delineation of an exploration program to provide an overview of the placer mineral resources offshore Nova Scotia.

As a result of the present work, it is now recommended that additional work should be carried out before the work program outlined above is undertaken. Further comments on this are given below and, for convenience, each of the three components of the program, i.e.

- drilling/sampling equipment
- mineral processing system
- exploration program

are dealt with separately.

6.2 DRILLING/SAMPLING SYSTEMS

6.2.1 Proposed "at-sea" Field Trials of Existing Systems

Evaluation of the existing drilling and sampling systems carried out as part of the present project (see Sections 5.4, 5.5 and 5.6) has shown that none of the existing systems included in this study is able to meet all of the performance and other objectives considered applicable in the present context (see Section 5.2). Nevertheless, an attempt has been made to select existing equipment which most nearly meets the revised objectives for Reconnaissance Surveys (Category 1) and Detailed Investigations (Category 2), as defined in Section 5.6.1. The systems selected on this basis are as follows:

Category 1 - Primary System

- Alluvial Mining Vibro-Impact Corer

Possible Alternative Category 1 Systems

- Geodoff I (Mark 2)
- Aimers McLean/BGS Vibrocorer
- Alpine Vibracore
- Geomarex P4 Vibrocorer
- Haamer Vibrocorer

Category 2 - Primary System

- Alluvial Mining Amdril

As outlined in Section 5.4, the equipment evaluation which has resulted in selection of the systems listed above, has been based primarily on brochures and other information provided by the manufacturers. For many of the systems there appears to be little published factual data on the performance of the equipment in sampling placers or placer-like deposits. Therefore, in order to check and validate the assessment, comparative trials at sea are required with a number of these systems (particularly the alternative systems listed in Category 1) before a meaningful final selection can be made. These trials would also provide crucial information on the suitability of various drilling/sampling concepts in the context of this project, which would be extremely valuable if it is decided to proceed with development of a purpose-built drilling/samping system (see Section 6.2.2 below).

It is recommended that the field trials should be carried out as part of Phase III of the project. The number of systems which can be included in the comparative trials will depend primarily on the level of funding which can be made available for the next phase of the project.

The trials should preferably be carried out in areas known to contain gold-bearing placer deposits and covering the full range of facies types (see Section 3.0). In this connection, the assistance of Energy, Mines and Resources, Canada and the Nova Scotia Department of Mines and Energy will be required to obtain access to the results of previous exploration work, so that a suitable site may be selected.

As part of the trials, particular attention should be given to the question of whether counterflush (i.e. reverse circulation) and airlift drilling systems provide samples which are sufficiently representative of the in-situ material to permit an accurate determination of gold content. There appears, at present, to be conflicting opinions and reports on the degree to which migration of denser particles (e.g. gold) occurs with systems of this type and the effect of factors such as this on the resulting economic evaluations. In the present context, this would appear to be a fundamental point which needs to be resolved before a realistic final equipment evaluation and selection can be made.

It is proposed that in selected areas, duplicate samples of sufficient size to permit accurate determination of gold content should be taken with each of the various sampling systems under test. In designing the sampling program, particularly in determining the number of samples to be taken in one area with one piece of equipment, allowance should be made for possible variations in gold content from place to place within the same sample area.

For preliminary budgetary purposes, the cost of a three week field programme to carry out comparative performance tests with various sampling systems as outlined above, is estimated to be on the order of $400,000. The actual cost will depend on the number of systems to be tested, the number of sample stations to be included in the test program, and the location of the test sites.

6.2.2 Development of New Purpose-built System

In view of the fact that none of the existing systems evaluated meet all of the objectives of this project, it is recommended that consideration should be given to development of a new Canadian-made, purpose-built placer sampling system which is designed to cater to the geological and environmental conditions anticipated in areas such as offshore Nova Scotia (see Sections 3.0 and 5.1.4, and Appendix B) and other Canadian coastal areas, and also the operational, performance and economic criteria developed for the present project (see Section 5.2). Although developed to cater to Canadian conditions, it is likely that such a system could subsequently be marketed outside Canada.

The following drilling/sampling concepts appear to warrant consideration in this connection:

Remotely Controlled Bottom Mounted Systems

- Rotary drilling using a large diameter, double or triple tube corebarrel to obtain relatively undisturbed core samples and/or a counterflush airlift system to obtain continuous, disturbed samples. The C-CORE Drill concept could form the basis for a system of this type.

- Hollow stem auger with an internal sample tube to provide relatively undisturbed core samples and/or a counterflush airlift system to obtain a continuous disturbed sample. A simplified version of the NORDCO SeaDrill II could form the basis for this type of system.

- Combination of vibro-impact hammer and rotating corebarrel to provide relatively undisturbed core samples. It is considered that rotation of the corebarrel has the potential to reduce significantly soil friction against its inside and outside surfaces and that this could materially improve both corebarrel penetration and sample recovery.

Shipboard Operated Systems

- Smaller version of the hammer drill with a heave-compensation system, possibly with the option of rotating the corebarrel during driving to reduce friction on the outside of the barrel and thereby minimize the pullout force required. The system would use the counterflush method to provide a continuous, disturbed sample to the surface.

- Hydraulic or pneumatic downhole hammer to drive a sample tube ahead of the casing, with the casing then being advanced by driving or rotary drilling to the next sampling depth. A heave compensation system should preferably be incorporated into the drilling system.

Further study and the results of comparative trials with existing systems (see Section 6.2.1) may indicate other concepts which also warrant consideration as the basis for a purpose-built system. Since the trials could provide valuable information on the suitability of various drilling and sampling concepts to meet the objectives of this project, it is recommended that the comparative field trials with selected existing sampling systems outlined in Section 6.2.1 should be carried out even if the intention is eventually to proceed with development of a new system.

6.3 PROCESSING REQUIREMENTS FOR OFFSHORE GOLD-BEARING PLACER DEPOSITS

The primary objectives of the mineral processing work carried out as part of the present project were to identify the mineral associations present in the samples tested and to determine the metallurgical process(es) which would result in optimum recovery of the gold. This work was severely hampered by the low gold content of the samples provided for testing. Consequently, a significant amount of further testing on new samples is considered to be necessary before any meaningful conclusions can be drawn in relation to this phase of the work. Witteck has recommended that a 20 tonne sample should be provided for this purpose (see Recommendations in Appendix C). It is considered that any future metallurgical testing work could with advantage be carried out separately from the other components of the project. Companies and individuals with knowledge of drilling and sampling systems do not necessarily have appropriate experience in, and facilities for, mineralogical processing, and vice-versa.

The original intent was that Phase III of the project would include the design and development of an onboard processing system to recover minerals from the drill cores. At present it appears that it may be preferable to consider carrying out only preliminary sample preparation at sea, and to transfer prepared samples ashore for processing and assay. However, as noted above and in Appendix C, further work is required before any definite conclusions can be drawn on this aspect of the work.

6.4 RECONNAISSANCE EXPLORATION PROGRAM

An effective exploration program designed to provide a meaningful overview of the placer resources offshore Nova Scotia represents a major undertaking requiring considerable detailed planning. Availability of an effective system capable of providing samples which are reliably representative of the in-situ material is an essential prerequisite for this type of program. Because of this, it is recommended (see Section 6.2) that further work aimed at selecting or developing a suitable sampling system(s) should be carried out prior to undertaking the main exploration program.

Assuming that a suitable sampling system has been chosen and field-tested, it is proposed that the exploration program proceed through the following stages.

A) Literature Review-Offshore Geology

Compile all necessary background information relative to placer exploration on the Scotian Shelf including the following:

i) Bedrock Geology

- Lithologic character and distribution, with particular reference to the possible location of gold deposits;
- Bedrock morphology, with particular reference to structural and glacial controls on the distribution and extent of drowned river and glaciofluvial channels;

ii) Glacial History

- Timing and areal extent of ice on the Scotian Shelf;
- Flow patterns of glacial ice and location of drainage channels;
- Sea level history, with particular reference to the delineation of drowned beach terraces;

iii) Surficial Geology

- All existing literature pertaining to the distribution, textural characteristics and thickness of the sub-facies of the Sable Island Sand and Gravel Formation (King, 1970) defined in Section 3.0 and Appendix B of this report;
- Any available information on facies controls;

iv) Exploration History

- Any and all available information concerning past or present offshore exploration carried out by Ocean Science and Engineering, Seabright, Mer Resources, etc.

B) Selection of Target Sites

Once all available background information has been compiled, a number of sites should be targeted for sampling. Target sites should be selected to provide complete geographic coverage of the shelf and to sample as wide a variety of geological environments as possible. This will require an astute synthesis of the available geological and exploration history information, as well as taking account of any restrictions imposed by the sampling system to be used. (e.g. Maximum operating water depth, sediment types which can be sampled, maximum depth of penetration in relation to anticipated overburden, thickness above target zone, and other considerations.)

C) Field Program

The field program should involve two components. The first will be the design of geophysical survey methods most suited to placer exploration on the Scotian Shelf. It is considered likely that a depth sounder, side scan sonar and sub-bottom profiler will be required to document the conditions at each sample site. Use of these systems will optimize selection of sample site locations and allow for extrapolation of the findings to other areas with similar geological conditions. The layout of survey lines (spacing, orientation) will vary for each target depending upon size and geometry.

The second component of the field program will be establishment of a detailed sampling pattern for each target site. This will require an estimate of the probable placer deposit size and geometry; an evaluation of sample size requirements based on texture of the deposit; consideration of sample depth and spatial requirements; and an estimation of gold particle size and distribution.

APPENDIX A

Statement of Work - Phase I and II

.PPENDIX "A"

14SQ.23440-5-9230
0SQ85-00287

STATEMENT OF WORK

BACKGROUND

Information on offshore placer exploration programs for gold, tin and other heavy minerals indicates that a professional assessment into the adequacy of available offshore placer coring and drilling, mineral processing equipment and a cursory examination of the potential value from offshore placers would be extremely useful. Canadian entrepreneurs cannot individually justify the effort required to: 1) compile information on offshore placer drilling equipment, 2) determine the processing requirements to recover the mineral from the mineralized material, and 3) produce a feasibility report describing the equipment requirements, costs and program necessary to define the offshore placer reserves.

This Request For Proposal will be directed to firms processing multi-deciplinary engineering skills, with experience in sampling and processing of placer deposits, especially those located offshore.

Information provided by the study will save Canadian entrepreneurs considerable time and effort and increase the likelihood that offshore placer sampling strategies will provide meaningful results. In addition, the work may lead to the development of Canadian drilling technologies suitable for use on fishing boats. This will provide work for Canadians and possibly lead to opportunities for overseas sales of services and technology, in response to the efforts of numerous nations to explore for seabed mineral resources within their Exclusive Economic Zones as established pursuant to the recent United Nations Convention on the Law of the Sea.

REQUIREMENT

On behalf of the Department of Energy, Mines and Resources; investigate the drilling devices which may be suitable for sampling of offshore placer deposits; process gold bearing samples from offshore placers to determine the mineral processing requirements to recover gold; and to produce a Statement of Work for a prefeasibility report which describes, engineers and estimates the cost of a twelve (12) month exploration program, drilling and sampling placers from a small fishing vessel.

7

PHASE I

Compile Information on Offshore Placer Drilling Equipment

The contractor will produce a comprehensive report assessing the capability and suitability of available drilling technologies that might be used for placer exploration in the Canadian offshore. The report should also include costs and terms of purchase/lease of the various systems examined as well as suppliers. Recommendations will be made on possible improvements and the potential for modifying existing equipment for use on coastal fishing vessels so as to decrease the cost of exploration and create employment opportunities for Canadian fishermen. As an additional requirement of this report, the contractor shall prepare a Statement of Work and cost proposal for the Phase III section of this project. This Statement of Work will address the requirements for preparing a feasibility report with engineering and costs data describing sample recovery systems and sampling programs. This Statement of Work will include a cost proposal to complete this work.

PHASE II

Determine the Processing Requirements for Offshore Placer Reserves

The contractor will arrange to process four (4) bulk placer gold samples presently being recovered from private offshore exploration work. The processing studies will identify the mineral associatins, and determine the optimum recovery methods using gravity, flotation and magnetic separation mineral processing techniques.

APPENDIX B

Geology of Placer Deposits - An Overview

1. INTRODUCTION

The objectives of this report are to a) provide a general overview of marine placer genesis and occurrence and b) to identify and describe those geologic factors which warrant consideration in the design of a placer exploration program on the Scotian Shelf. Discussions include placer genesis, the global distribution of placer deposits, a brief review of the geologic and oceanographic setting of Atlantic Nova Scotia, characterization of the Scotian Shelf sediments and five potential placer type deposits and a short review of the sample size required for placer gold exploration.

2. PLACER GENESIS

Selective sorting by size and density under specific hydraulic conditions may result in placer formation (Slingerland, 1984). The distribution of heavy minerals within a depositional area is related to both source area and the modern or past hydraulic regime. These factors will be reflected by the relative concentrations of heavy minerals, the individual mineral distributions and heavy and light mineral association patterns. The latter relationship forms the basis of hydraulic equivalence (Rubey, 1933; Rittenhouse, 1943) which states that those hydrodynamic conditions allowing for the deposition of quartz grains of a certain diameter would also allow the deposition of heavy minerals (of a smaller size) having the same settling velocity.

More recent studies have shown that standard hydraulic equilibrium is inapplicable to many natural non-cohesive sands because of the interaction and complexity of grain size, density, shape and mode of sediment transport (Slingerland, 1977; Barrie, 1981; Reid and Frostick, 1985). Three possible explanations have been defined for this divergence. They are (1) size restriction inherent in certain minerals from source (2) chemical decomposition and (3) differential entrainment of mineral grains (related to shape and density). It is the third process under different combinations of wave and current acting on a seabed or fluvial channel of variable roughness which can lead to the formation of heavy mineral enrichment and placer potential. Larger, light mineral particles, are selectively entrained as they stand proud of the bed, and as such, are subject to greater lift and drag forces. Deposits of the lighter heavy minerals such as cassiterite (tin), ilmenite (titanium), rutile (titanium), zircon are thus characterized by a well sorted sand facies.

Gold, under standard hydraulic equivalence, will be associated with gravels. Moreover, since the size contrast is so great, interstice entrapment of gold particles becomes a significant factor (Minter and Toens, 1970). Where gravels fine upward the interstices tend to be uniformly packed and are the most suitable for placer development (Reid and Frostick, 1985). The physical shape of gold may also be of significance in entrainment and deposition; gold flakes move in a similar fashion to other fine grained platy minerals and are transported large distances from source. Particulate gold, on the other hand, will tend to settle quickly, in close proximity to its primary source.

3. PLACER DEPOSITS

Heavy heavy minerals such as gold and platinum, and light heavy minerals such as cassiterite (tin), ilmenite (titanium), rutile (titanium), zircon, chromite, magnetite and zircon have all been mined as marine placers. Gemstones (e.g. diamonds) are also found as marine placers. Significant concentrations vary depending on the relative economic value of the mineral constituents (e.g. economic deposits of tin or ilmenite are over 800 times more concentrated than gold).

Globally, offshore placer mineral production has been dominated by cassiterite (e.g. Malaysia, Thailand, Indonesia) diamonds (e.g. Nambia), gold (e.g. Philippines) and iron sands (e.g. Brazil). In addition, beach mining of these same minerals plus ilmenite, rutile, zircon, plantinium, chromite and monazite is ongoing in several localities including Australia, Brazil, New Zealand, USA, Sri Lanka and the Philippines. Recent offshore discoveries include titanuim and zircon deposits found off India (Siddiquie et al., 1982) and Sri Lanka (Meyer, 1983).

Within Canada, placer gold has been mined from beach placers on Vancouver Island, the Queen Charlotte Islands, British Columbia(B.C.) and eastern Nova Scotia (Hale and McLaren, 1984). Iron sands (ilmenite and magnetite) have been identified on the north shore of the Gulf of St. Lawrence (Frazier and Ayer, 1973).

Concentrations of ilmenite, zircon and vanadium (> 1.0%) occur nearshore off northeast Graham Island and the banks of Queen Charlotte Sound, B.C. (Barrie et al., 1986). Chromite concentrates occur in Port au Port Bay, Newfoundland (Hill and Ruest, 1981).

4. NOVA SCOTIA PLACER GOLD

4.1 Introductory Statement

Three factors are needed for the development of gold placers: a source, liberation of gold from the source by mechanical or chemical weathering, and a means of concentrating the gold, usually by hydraulic flow. The auriferous lode deposits of the Nova Scotia Meguma metasediments, the extensive mechanical abrasion and transport of these metasediments by Wisconsin glaciers and the high energy conditions associated with a transgressing sea level (discussed in more detail below) enhance the placer potential of the Scotian Shelf. For these reasons the Scotian Shelf has been targeted as a favorable site for placer gold exploration (Hale and McLaren, 1984).

The genetic development and characteristics of the Scotian shelf sediments and six potential placer types are discussed with reference to those criteria warranting consideration in an exploration drill program. Discussion of the sediment facies is restricted to water depths of < 100 metres as this is considered the practical limit for marine dredging operations. The data provided are estimates only and cannot account for local variations across the shelf. An extensive drilling program, such as that outlined in Phase III of the present contract, should provide the necessary verification.

4.2 Geologic Setting

The bedrock geology of the inner Scotian shelf (< 100 m water depth) is largely an extension of that observed on land and is defined by King and MacLean (1976) as undifferentiated Meguma Group metasediments and Devonian granites. The Meguma Group is divided into the lower Goldenville Formation quarzites and upper Halifax Formation slates. The granites are coarse grained, often porphyritic and are composed largely of quartz, biotite and orthoclase feldspar. The Meguma Group is tightly folded into a series of northeasterly trending synclines and anticlines which are offset by large northwesterly trending sinistral faults.

Gold occurs within quartz veins of the Goldenville Formation. Auriferous veins are generally limited to dilation zones within the crests of fairly sharp folds and are hence known as saddle-reef type deposits. Over 35 million grams of gold have been won from these lode deposits (Samson, 1984). It has been speculated that a minimum of 50 favourable sites for gold mineralization may exist within the Meguma bedrock on the Scotian shelf proper (Fowler and Miller, 1985).

The floating terminus of the mid-Wisconsin ice sheet over the Scotian shelf is marked by a submarine end moraine complex located 30-50 km offshore (King, 1970). This terminus also demarcates the offshore limit of the Meguma Group metasediments.

With recession of the ice sheet, the shelf experienced a period of isostatic rebound, lowering sea level by approximately 120 metres. The following transgression was incremental with many advance/retreat cycles. Sea level rise has been continuous for the past 5000 years at an average rate of 30 cm/100 yr (Scott, 1979).

4.3 Oceanographic Setting

Atlantic Nova Scotia may be classified as a storm-dominated environment. During the winter months, winds blow offshore and waves are characterized by significant heights of 4 m and periods of 6-8 s. During the summer, winds blow from the southwest with significant wave heights averaging 1-2 m and periods of < 5 s (Walker, 1984). Storm conditions within the nearshore zone of Atlantic Nova Scotia are characterized by wave heights of 5 m and periods of 4-7 s (Vandall, 1976). Figure 1 illustrates the per cent of time a given wave height is expected to be exceeded (the data is based on yearly averages).

Longshore and current velocities vary from 5-40 cm/s with an average fair-weather velocity of 12 cm/s (Munroe, 1980). Tides are semi-diurnal with a mean tidal range of 1.4 metres. Tidal currents are orientated perpendicular to the coast and are characterized by velocities of 25 cm/s (Miller et al., 1985).

During severe ice years Atlantic Nova Scotia is subject to land-fast ice during January and February. The ice reaches maximum thicknesses of 0.45 metres but is generally less than 0.3 metres (Miller et al., 1985).

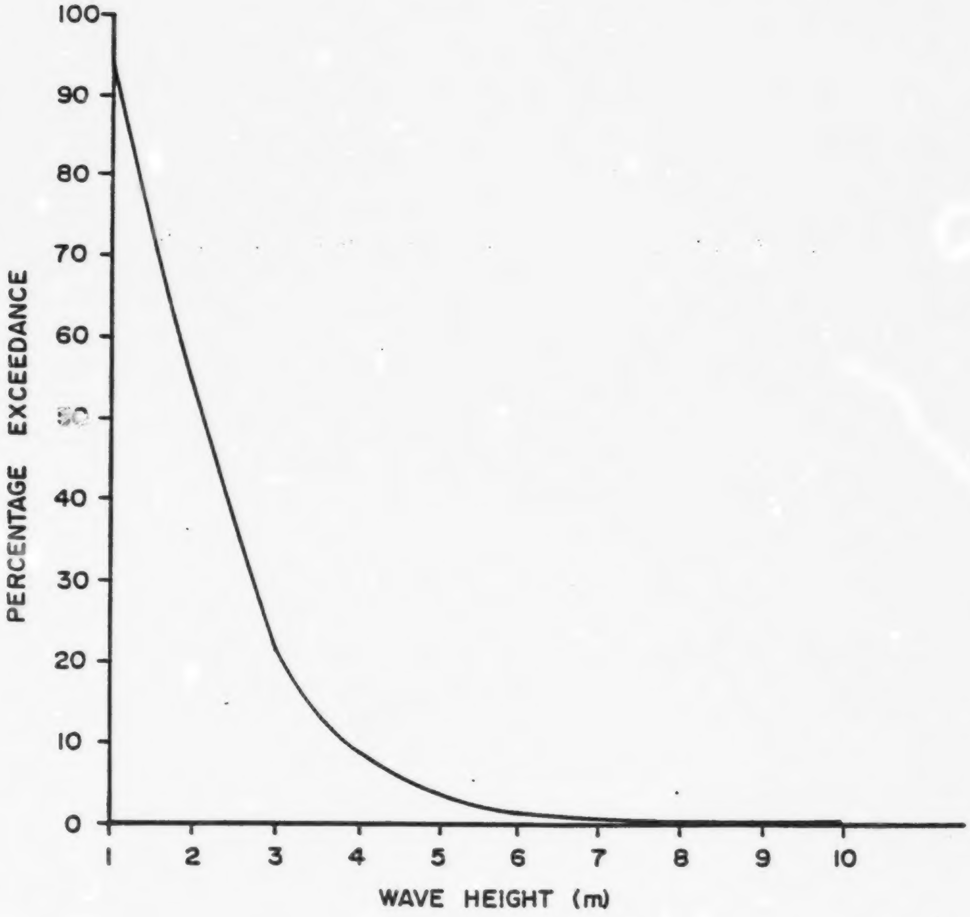


FIGURE 1. Percentage Exceedence For Given Wave Heights (After Walker,1984).

4.4 Scotian Shelf Sediments

The bathymetry of the Scotian shelf is highly irregular, reflecting in part the relief of the underlying bedrock and, to a lesser extent, drowned glacial features. Prominent bedrock shoals and over-steepened "fjord-like" basins characterize the inner shelf area. The morphological development of the bedrock surface is thought to be the result of both glacial quarrying and meltwater erosion (Piper et al., 1985).

The unconsolidated sediments of the Scotian shelf can be grouped into 4 facies: lag gravel, gravelly-sand, muddy-sand and glacial drift facies. A summary of facies characteristics is provided in Table 1. A schematic representation of facies stratigraphy is illustrated in Figure 2.

The present sediment distribution is the direct result of glacial drift "unmixing" through marine reworking by a transgressing sea level (Emory-Moore, 1985). Facies 1 represents a blanket of glacial drift that was deposited during the advance and retreat of glacial ice over the shelf during the Wisconsin stage. Facies 2 represents the coarse gravel end-member of the glacial drift and is stable (i.e. forms a pebble armour) under present marine conditions. Facies 3 is presently being "unmixed" with sediment mobility restricted to the sand subfacies. Upon further sea level transgression and subsequent marine reworking, facies 3 should acquire the characteristics of facies 2 (i.e. become a gravel lag deposit). Finally, facies 4 is a blanket of modern sands with minor muds (note muds are restricted in occurrence to protected embayments) which are highly mobile and

	Facies 1	Facies 2	Facies 3	Facies 4
Mean grain size (mm) (max-min)	.5 (64-.05)	16 (64-4)	2.4 (8-1)	.125 (.25-.0625)
Mean Sorting	.8-4 (moderate-very poorly)	1.2 (poorly)	2.5 (very poorly)	2.8 (very poorly)
Mineralogy	-quartzite -slate -granite -basalt -quartz, mica and feldspar	~ 70% quartzite ~ 20% slate ~ 8% granite ~ 2% misc.	80-90% quartz	~ 65% quartz ~ 15% feldspar ~ 10% mica
Thickness (m)	0-100 (avg. ~ 15)	0-10	0-10	0-5
Water Depths (m)	0-100	10-100	0-60	0-19
Present Mobility*		< 13 m	< 24 m coarse < 38 m fine	< 39 m
References	King (1976)	Emory-Moore (1985)	Emory-Moore (1985)	Emory-Moore (1985)

Table 1. Characteristics of Scotian Shelf Sediments

* This is a measure of the maximum water depth at which a given sediment will move under storm conditions (assumed T = 7 sec, H = 4 m).

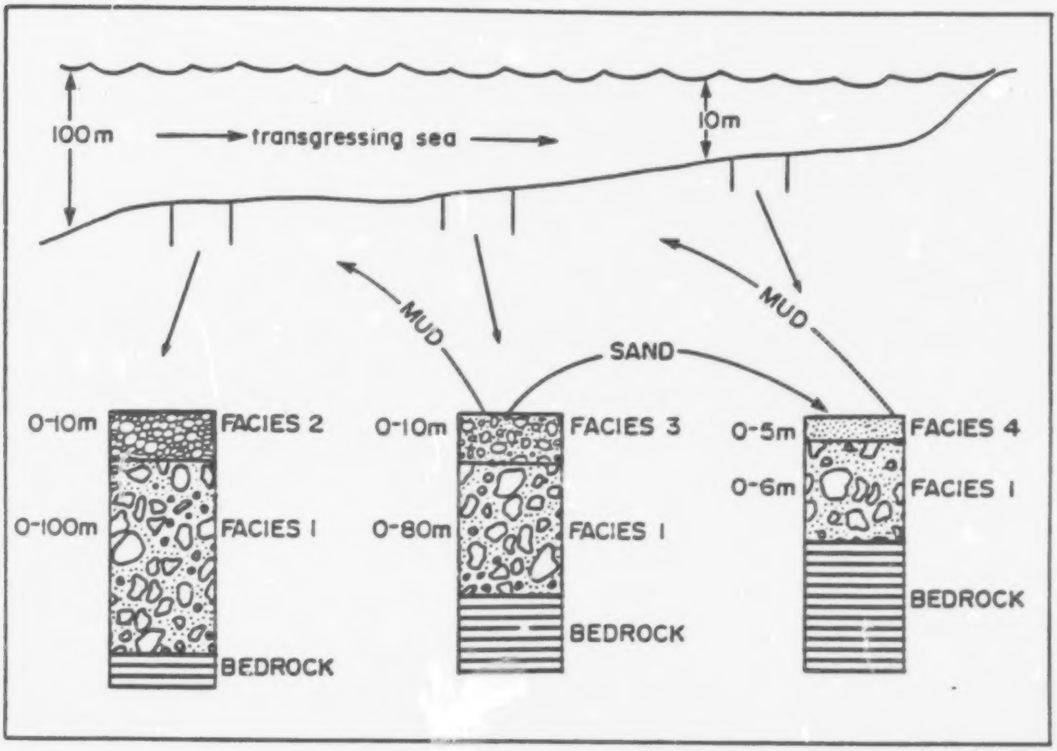

100m
transgressing sea
10m
MUD
MUD
SAND
0-10m
FACIES 2
0-100m
FACIES 1
BEDROCK
0-10m
FACIES 3
0-80m
FACIES 1
BEDROCK
0-5m
FACIES 4
0-6m
FACIES 1
BEDROCK

FIGURE 2. Stratigraphy of Scotian Shelf Sediments(After Emory-Moore,1985).

continually moved shoreward with the transgressing sea. Facies 4 is the finer end-member of the original "unmixed" glacial drift.

4.5 GOLD PLACERS: FACIES DESCRIPTION

Marine gold placers may occur within five deposit types on the Scotian Shelf: glaciomarine, isolated detrital lag, glaciofluvial, relict alluvial and submerged beach. The following discussion will focus on generalized characteristics of each deposit type with reference to known data for the Scotian Shelf. Table 2 summarizes the characteristics of the five placer types.

Glaciomarine

Given that glacial drift on the Scotian Shelf reflects closely the underlying bedrock and that glacial transport in many cases was at most two kilometres (Grant, 1963), anomalous gold concentrations may occur in drift which lies in close proximity to a primary bedrock source. The unconsolidated glacial drift deposited landward of the mid-Wisconsin end moraine complex (i.e. at < 120 meter water depths) may be considered comparable in texture and mineralogy to the onland glacial deposits. Diablo (1984) found that near Oldham Nova Scotia gold abundances in on land tills of greater than 10ppb form a dispersal train 1900 m long while concentrations of between 40 and 100 ppb occur in clusters up to 600m down-ice from the source bedrock (i.e. Meguma metasediments). MacEachern et al., (1984), in a similar study, found that gold within the till was in the form of small flakes

	glaciomarine	lag deposits	glaciofluvial	relict alluvial	submerged beach
mean grain size (mm)	.05-1	16	4-16	4-16	.35
mean sorting	.8-4 (moderate-poorly)	1.2 (poorly)	1.5 (poorly)	1.5 (poorly)	.5 (poorly)
mineralogy	See facies 1, Table 1	See facies 2, Table 1			
overburden thickness	5-10m	0m	5-10m	10-100m	0-10m
facies thickness	1-90m	10m	25m	10m	5m
depth to bedrock	0	0-90m	0-60m	0-3m	0-90m
gold:-source	allocthonous	allocthonous and/or autochthonous	allocthonous	allocthonous	alloctonous
-size(mm)	<.0625 (flake)	<.0625	<.0625-.25	.25	<.0625 (flake)
-grades	10-100 pb	>500ppb			
preservation potential	high	high	high	low	high

Table 2. Placer Characteristics

and nuggets and concentrated in the <.0625 mm size fraction.

This type of placer deposit would be found within facies 1 on the Scotian Shelf and would have comparable textural and mineralogical characteristics.

Isolated Detrital Lag Deposits

Lag placer deposits are similar to glaciomarine deposits with the exception that they have been reworked by post-glacial eolian and transgressive marine processes. If the primary glacial tills are assumed auriferous (as suggested above) reworking of the sediment would tend to further concentrate the gold by differential entrainment processes. Gold, by virtue of its very high density and high sediment threshold, characteristically becomes trapped within the interstices of lag gravels. It has a tendancy to 'sift' through the sediment and come to rest on an impervious horizon such as bedrock.

The highly reworked gravel facies (#2, Table 1) of the Scotian Shelf provides an ideal setting for the development of lag deposits. Anomalous concentrations (> 500 ppb) of gold within facies 2 sediments off Country Harbour, Nova Scotia are classified as detrital lag deposits (Emory-Moore, 1985). It may be suggested that in such a deposit gold would concentrate at either the interface of reworked gravels (facies #2) and the impervious (?) underlying glacial drift (facies #1) or, the bedrock surface (depending on the relative thickness of each facies). If the source of the gold is glacial drift the deposit would be allocthonous. Gold derived from the underlying bedrock and remaining in situ is autochthonous.

Relict Alluvial

Gold placers can form in present and past water courses such as gulches, creeks, rivers, flood plains and deltas. Gravity settling of gold and subsequent differential entrainment of light minerals is the dominant process.

Gold is characteristically found in the lower layers of alluvium, usually in loose unconsolidated gravels, either on bedrock (in crevices or fractures) or in a zone within 3-5 m above bedrock. Particulate gold fines downstream from its source where it is widely dispersed; the closer to source, the richer the alluvial placer. Burial of the placer by glacial till, marine sediments, submergence etc. enhances preservation potential and results in the formation of relict alluvial type deposits.

The effect of glaciation is generally to erode pre-glacial placers in valley bottoms and to disperse the gold within the glacial drift. Within Nova Scotia, those alluvial placers formed during pre-glacial times in narrow valleys which lie transverse to the direction of glacial movement may however, have been preserved and now lay buried beneath glacial drift. No relict alluvial placers have been identified on the Scotian Shelf yet the seaward extension of ancient and recent stream channels may provide suitable exploration targets.

Glaciofluvial Deposits

Streams which flow underneath or issue from beneath glaciers provide large volumes of meltwater characterized by high sediment load capacities. Such streams and rivers often assist in placer formation by: a) winnowing away light minerals thereby leaving residual lag gold and b) churning up of the load and allowing the gold to sink to the bottom. Particulate gold may be derived from glacial drift or from the direct erosion of auriferous bedrock.

Gold distribution and textural characteristics of glaciofluvial deposits are similar to those described for relict alluvial deposits. The very large carrying capacities of glaciofluvial systems would however create much thicker and more laterally extensive fluvial facies; gold may therefore be expected to concentrate further downstream from its source.

Although glaciofluvial placer gold deposits have not been identified offshore southern Nova Scotia, the several deeply incised glaciofluvial channels characteristic of the shelf (e.g. offshore Country Harbour) hold high potential for such deposits.

Submerged Beach

Beach placers are formed by the winnowing action of waves and currents (longshore and tidal) along present and past shorelines. Quartz pebbles and sand predominate with the gold (usually fine grained) found in close association with basal gravels. The pay streaks often follow the strand line and commonly measure 0.1 - 1.0 m in thickness and 3 m - 90 m in width (Boyle, 1979).

Modern beach placers in the Ovens district of Nova Scotia produced over 130,000 grams of gold during the late 1800's. These deposits were formed by the wave erosion of Meguma bedrock and till bluffs which border the coastline. Marine reworking of the sediment along the beach led to the concentration of gold in the sands, especially in the crevices of underlying bedrock. Gold in these deposits is fine grained, flaky and commonly associated with pyrite and arsenopyrite.

The incremental nature of the transgressing sea level over the Scotian Shelf has resulted in the development of several beach terraces and sea scarps (Samson, 1984). These features, now drowned, may contain anomalous concentrations of gold. The gold may have initially been concentrated in a manner similar to the Ovens district and concentrations further enhanced by the continual winnowing effects of a transgressing sea.

4.6 SUMMARY

Those geological parameters to be considered in the development of a drill suitable for placer exploration on the Scotian Shelf are:

(i) a range in grain size of .0625 to 64 mm

(ii) moderate to very poorly sorted sediment

(iii) bedrock and pebble lithologies are largely quartzite, slate and granites

(iv) the presence of land-fast ice during January and February

(v) high wave energies characteristic of Atlantic Nova Scotia

(vi) sediment thickness of 0-100 m

(vii) capability of drill penetration to, and slightly into, bedrock (placer enrichment generally occurs at or near the bedrock-sediment interface)

5. SAMPLE SIZE

Insufficient sample size (i.e. a sample not truly representative of the sediment and constituent economic minerals) may lead to inaccuracies in placer delineation and reserve estimation. This is especially true for noble metals where the particle sparsity effect of high unit value minerals is prevalent. Conventional techniques employed in the drilling of gold placers and computation of reserves do not generally give dependable estimates of grade.

Sampling programs must cater to the spatial and particle size distributions of gold and therefore usually involve both surface grabs and boreholes. Grab samples should weight at least 50-100 kg with a maximum distance between sample centres of 150 metres (Moore, 1978). Small diameter boreholes (e.g. < ~ 6 cm) are generally used to ground truth geophysical data with regard to depth of overburden, presence of buried channels and limit of the deposit. Larger diameter boreholes are required for accurate economic determinations. Clifton et al. (1969) calculated the sample mass required for a given particle mass. Assuming a uniform shape and density of gold, and a sample interval of one metre, Dimock (1985) used Clifton's data to estimate the core diameter necessary for accurate sampling of various deposit grades (fig. 3). A borehole density of approximately one hole for every 4 to 16 sq km is considered the density at which additional boreholes will not affect the estimate of gold within the deposit (Fricker, 1976).

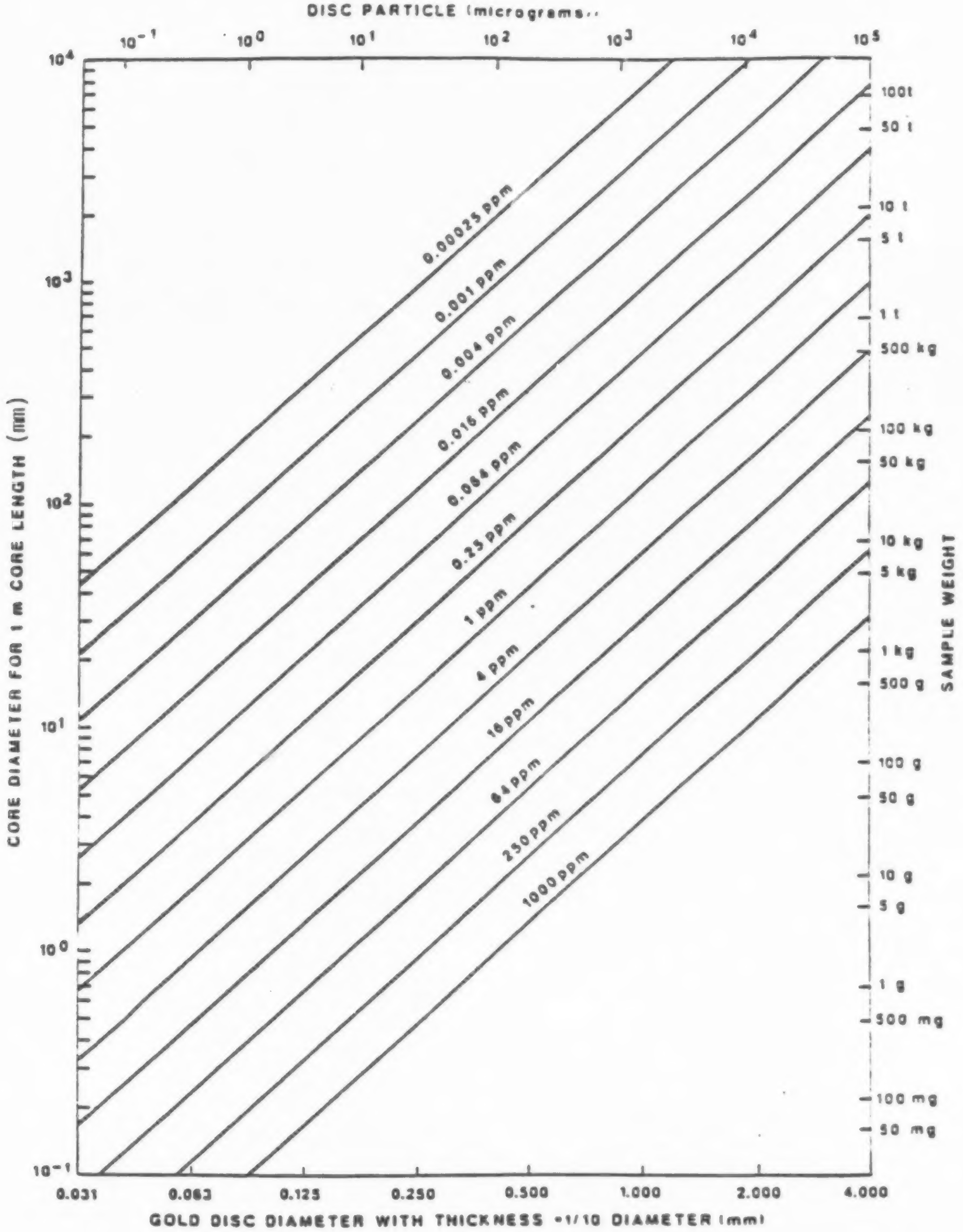


FIGURE 3 .GRAPH TO DETERMINE SAMPLE SIZE FOR DISCOIDAL PARTICLES(From Dimock,1986).

APPENDIX C

Bulk Sample Analysis Results

WDI
WITTECK DEVELOPMENT INC.
2640 South Sheridan Way, Mississauga, Ontario, Canada L5J 2M4
Telephone: (416) 823-7381 Telex: 06-982328

METALLURGICAL TESTWORK AND PROCESS REQUIREMENTS FOR OFFSHORE PLACER RESERVES

Project No. 5196
for

Nordco Limited
P.O. Box 8833
St. John's, Newfoundland
A1B 3T2

May, 1986

G. A. Karklin as per W. J. Witte
G. A. Karklin,
Manager, Project Development

Greg Davison
G. Davison,
Head, Mineralogical Services

Bever
C. Bever,
Metallurgical Technician

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1.0 SUMMARY

Metallurgical testwork was completed on three samples of low grade gold ore from Nordco Limited of St. John's, Newfoundland.. Gold head analyses were completed for the bulk samples by using a multiple sample assay technique. The head assays for bulk samples A, B and C were 0.16, 0.15 and 0.05 g/t gold respectively.

Distribution of gold by size fraction indicates the presence of gold concentration in the finer fractions of the A and B samples. Preconcentration by screening was successful in upgrading Samples A and B. Sample C was of lower grade with slight concentration of gold in the coarser fractions.

Upgrading by gravity processing on one quarter of the A and B sample showed promising preliminary results. Tabling and vanning results were good but due to the fineness of the gold, jigging produced poor results. Jig test recovery of gold varied from 3.2 to 27.9%. Table and vanning test results varied from 16.2 to 76.5% gold recovery. These recoveries are based upon the samples tested and are not calculated from the ore prior to preconcentration.

Subsequent metallurgical testwork involving gravity, flotation and leaching of the fourth quarter of samples A and B indicated the following:

1. Recovery of gold from the -28 +65 mesh ore fraction by jigging was less than 1.0%.
2. Recovery of gold from the -65 mesh ore fraction was 78.4% by tabling, 30.7 to 58.9% by flotation, 94.7% by vanning and 91.0-99.0% by cyanidation.

These recoveries are based upon the feed subsequent to preconcentration.

Due to the lack of sample, it was impossible to perform an adequate number of tests in each of the metallurgical areas. It was also impossible to provide complete mass balances for some of the tests, because of the 30 gram sample requirement for low grade ore and the amount of several of the concentration products.

The mineralogical identification of particles in various metallurgical products, indicated minor sulfides, chloritized ferromagnesian minerals, quartzofeldspathic particles and various other minerals. Gold mineralization was observed as 70-75 micron irregular winglike placer particles with smooth grain boundaries.

This preliminary work indicates that preconcentration by screening, followed by gravity concentration using Reichert spirals, could provide an economic project, if a placer like operation is run on large tonnages of material.

2.0 INTRODUCTION

Three gold placer bulk samples were sent to Witteck Development following a request by Nordco Limited to provide metallurgical services in accordance with DSS Proposal No. 14SQ-23440-5-9230.

The objectives of the test program were to identify the mineral associations and determine the metallurgical process which would result in optimum recovery of the gold. A processing method for the bulk samples was developed to provide the requested metallurgical data. The data produced from the program included:

- accurate gold head assays
- distribution of gold with size
- metallurgical balances for upgrading by gravity processing
- identification of mineralogical associations and characterization of gold mineralization
- metallurgical balances for processing by flotation and leaching
- evaluation of data and preliminary flowsheet conceptualization.

Based on the results of the testwork, a preliminary flowsheet has been proposed.

3.0 PROCEDURES

3.1 Bulk Sample Preparation

Upon arrival, each of the three bulk samples were air dried. Following several stages of coning, quartering and mixing, each bulk sample was split into four representative quarter samples for subsequent metallurgical testwork (see Figure 1).

3.2 Preparation of Samples for Assay

The first quarter of each bulk sample (shown in Figure 1) was processed further as shown in Figure 2. As shown in the schematic, three head samples were split from each bulk sample quarter. All samples submitted for gold assay were ground by shatterbox and screened on a 200 mesh sieve. The oversize material was reground until the complete sample passed a 200 mesh screen. Other metallurgical samples were prepared using the same procedures.

3.3 Analytical Techniques

Due to the low grade of the gold placer samples, three samples were assayed for comparative results. All samples were fire assayed for gold and silver using a direct current plasma finish.

A single head sample from each of the three bulk samples was also analyzed for sulphur, copper, zinc, iron, arsenic and tin to identify the presence of any other potentially economic or environmentally sensitive elements.

The base metals were analyzed by acid dissolution followed by direct current plasma spectroscopy. Sulphur was analyzed by gravimetric methods followed by $BaSO_4$ precipitation. All solutions were analyzed directly by direct current plasma spectroscopy.

BULK SAMPLE PREPARATION

Figure 1

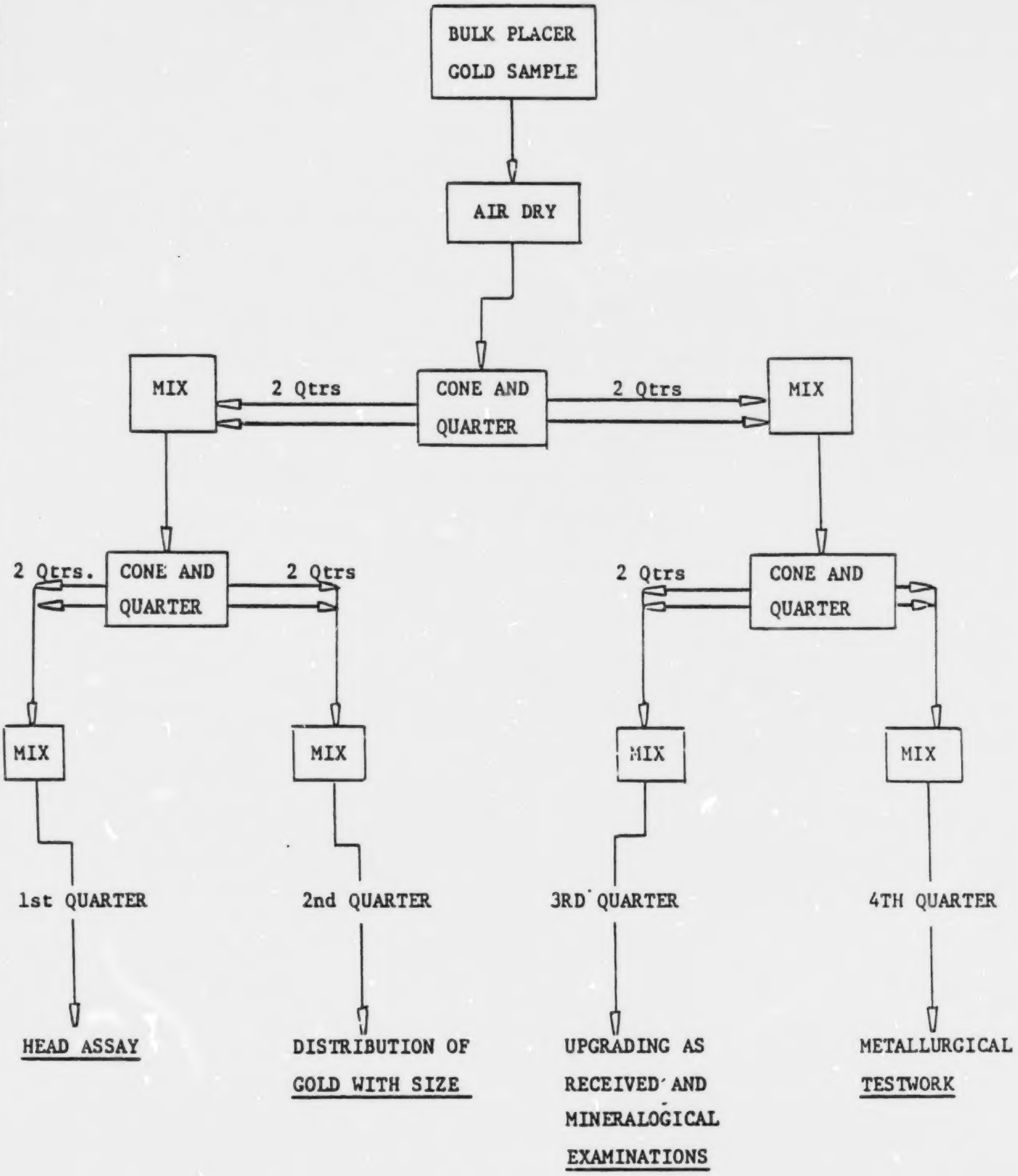
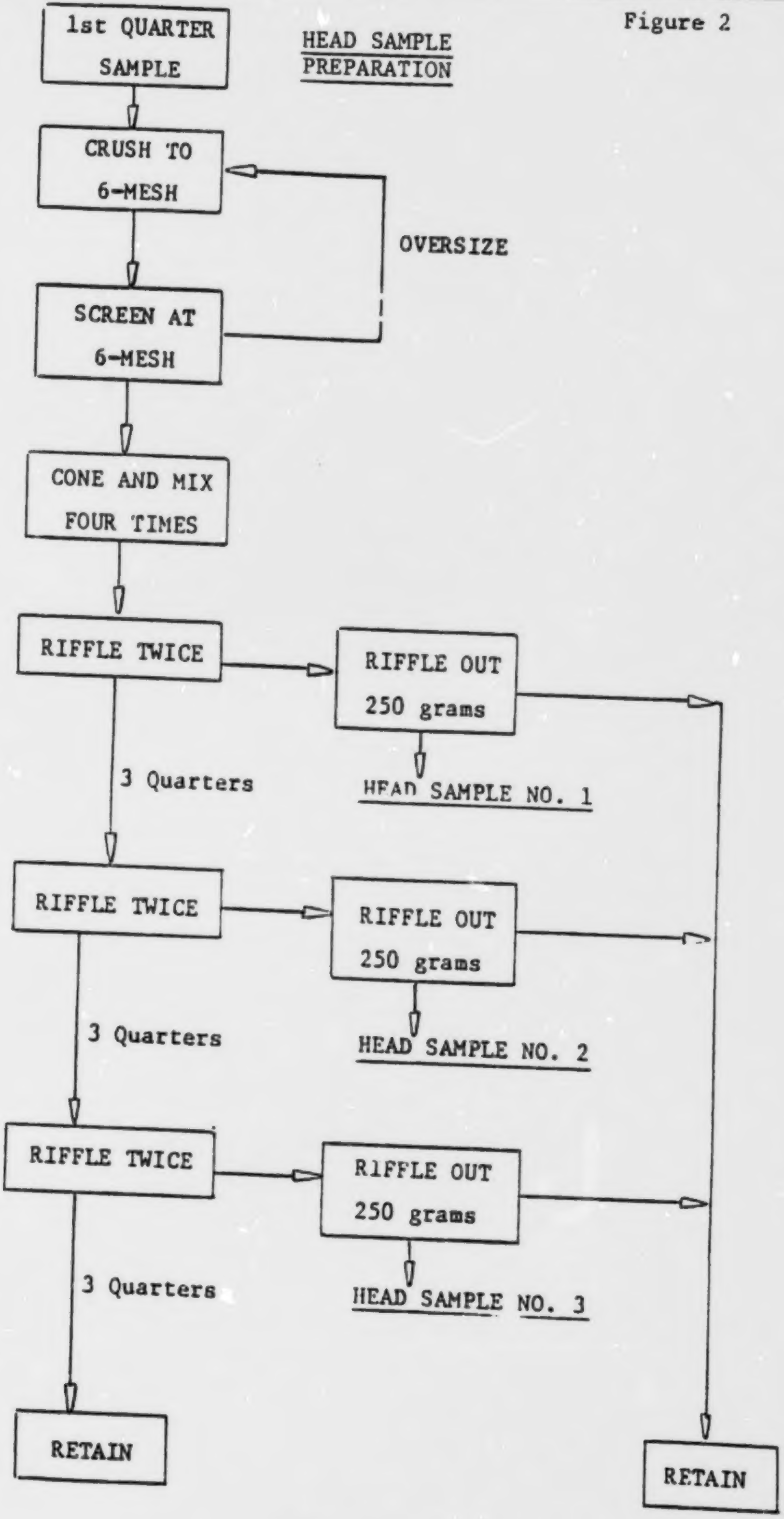

BULK PLACER GOLD SAMPLE
AIR DRY
CONE AND QUARTER
2 Qtrs
2 Qtrs
MIX
MIX
CONE AND QUARTER
2 Qtrs.
2 Qtrs
CONE AND QUARTER
2 Qtrs
MIX
MIX
MIX
MIX
1st QUARTER
2nd QUARTER
3RD QUARTER
4TH QUARTER
HEAD ASSAY
DISTRIBUTION OF GOLD WITH SIZE
UPGRADING AS RECEIVED AND MINERALOGICAL EXAMINATIONS
METALLURGICAL TESTWORK

Figure 2

HEAD SAMPLE PREPARATION


1st QUARTER SAMPLE
CRUSH TO 6-MESH
SCREEN AT 6-MESH
OVERSIZE
CONE AND MIX FOUR TIMES
RIFFLE TWICE
RIFFLE OUT 250 grams
HEAD SAMPLE NO. 1
3 Quarters
RIFFLE TWICE
RIFFLE OUT 250 grams
HEAD SAMPLE NO. 2
3 Quarters
RIFFLE TWICE
RIFFLE OUT 250 grams
HEAD SAMPLE NO. 3
3 Quarters
RETAIN
RETAIN

HEAD SAMPLES WERE PULVERIZED TO MINUS 200 Mesh

3.4 Screen Analysis

The second quarter of each bulk sample was shaken by hand and screened at one inch, one-half inch, one-quarter inch and 6 mesh. The minus 6 mesh material was blended and an 800 gram sample was riffled out. The sample was shaken by RoTap and screened on the following mesh sizes: 8, 10, 14, 20, 28, 35, 48, 65, 100, 150, 200, 270 and 325.

The screen fractions coarser than 6 mesh were crushed to minus 6 mesh and a 200 gram sample was riffled out and prepared for gold fire assays. Each of the remaining screen fractions were ground to minus 200 mesh and submitted for gold fire assays (one assay ton - approximately 30 grams).

Due to the small weight of the minus 100 mesh fractions in the B sample, several screen fractions were composited for gold fire assay. Similarly, composite samples were submitted for the A and C bulk samples from 150 mesh to -325 mesh.

3.5 Gravity Processing (Preliminary)

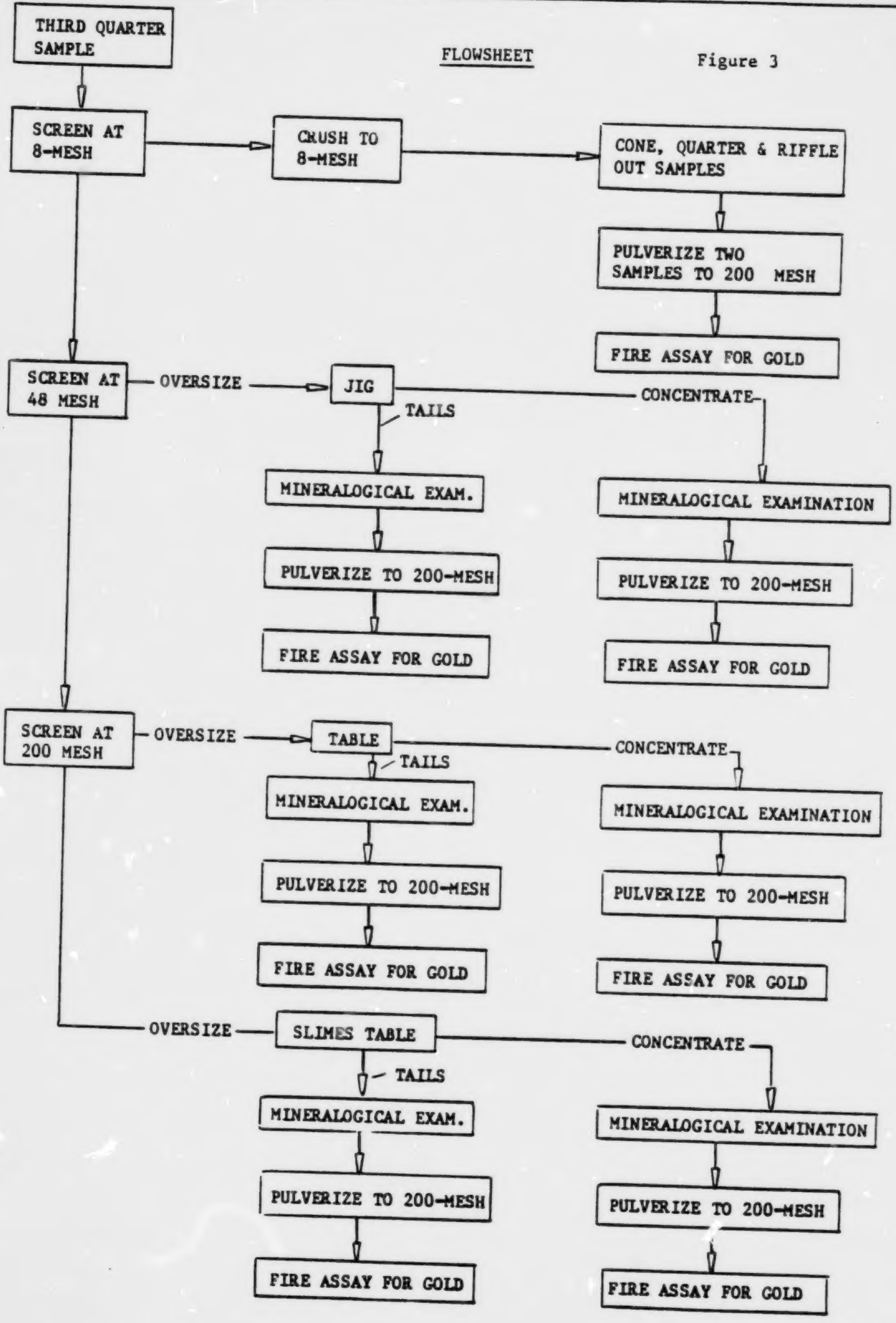
The third quarter of bulk samples A and B were processed as shown in Figure 3. The following is a brief description of the flowsheet.

The material was screened on 8, 48 and 200 mesh screens. The +8 mesh material was crushed to 100% minus 8 mesh and then rolled and blended. Two 200 gram samples were riffled out for gold fire assay.

The -8 +48 mesh material was blended by rolling and approximately 2 kg were riffled out to utilize as a feed sample for the jigging test. The jigging test produced a concentrate, bed and tailings product which were examined microscopically prior to submission for gold fire assays.

FLOWSHEET

Figure 3


THIRD QUARTER SAMPLE
SCREEN AT 8-MESH
CRUSH TO 8-MESH
CONE, QUARTER & RIFFLE OUT SAMPLES
PULVERIZE TWO SAMPLES TO 200 MESH
FIRE ASSAY FOR GOLD
SCREEN AT 48 MESH
OVERSIZE
JIG
CONCENTRATE
TAILS
MINERALOGICAL EXAM.
MINERALOGICAL EXAMINATION
PULVERIZE TO 200-MESH
PULVERIZE TO 200-MESH
FIRE ASSAY FOR GOLD
FIRE ASSAY FOR GOLD
SCREEN AT 200 MESH
OVERSIZE
TABLE
CONCENTRATE
TAILS
MINERALOGICAL EXAM.
MINERALOGICAL EXAMINATION
PULVERIZE TO 200-MESH
PULVERIZE TO 200-MESH
FIRE ASSAY FOR GOLD
FIRE ASSAY FOR GOLD
OVERSIZE
SLIMES TABLE
CONCENTRATE
TAILS
MINERALOGICAL EXAM.
MINERALOGICAL EXAMINATION
PULVERIZE TO 200-MESH
PULVERIZE TO 200-MESH
FIRE ASSAY FOR GOLD
FIRE ASSAY FOR GOLD

ALL PRODUCTS WERE WEIGHED, FIRE ASSAYED AND BALANCED TO PRODUCE A HEAD ASSAY

The -48 +200 mesh material was concentrated on a Deister Table using the sand deck. A concentrate and tailing product were produced. Following microscopic examination, the samples were submitted for gold fire assay.

A head sample was riffled out from the -200 mesh material for gold fire assay. The remainder of the -200 mesh material was vanned using a 25 cm porcelain vanning plaque. The -200 mesh material was gravity concentrated by vanning, rather than by slime deck table, due to the small amount of material in this fraction. The vanning produced a gravity concentrate and tailings products. After filtering and drying, the vanned tails were submitted for gold fire assay.

Due to the minute amount of the gravity concentrate, the concentrate gold grade was calculated by difference (assuming 100% gold mass balance).

3.6 Other Metallurgical Testwork

Based upon the preliminary screen analysis and gravity test data, the following metallurgical testwork was performed on the fourth quarter of the A and B bulk samples. The tests included gravity processing, flotation and leaching.

The A sample was screened at 28 and 65 mesh. The +28 mesh material was not processed due to the very low gold content. The -28, +65 mesh material was jigged and the -65 mesh material was used for tabling, flotation and leaching.

The B sample was screened at 65 mesh. The +65 material was not used due to low gold content. The -65 mesh material was used for tabling, flotation, leaching and vanning testwork.

3.6.1 Gravity Concentration

The -28, +65 mesh material from the A bulk sample and the -65 mesh material from the B bulk sample was jigged to produce a concentrate and tailings. A 200 gram sample was subsequently riffled from each product for gold fire assay.

A sample of the -65 mesh material was concentrated on the Deister Table using the slimes deck. A table concentrate and tailings product were generated from this test. A two hundred gram sample was riffled from each product for gold fire assays.

An additional 100 gram sample of the -65 mesh fraction was vanned to produce a vanned concentrate and tailings product. Each product was subsequently prepared and assayed for gold.

3.6.2 Flotation

Flotation tests were conducted on the -65 mesh fraction A and B material in a 500 gram or 250 gram flotation cell with a Denver D12 flotation machine. The pulp was conditioned for five minutes and the pH was brought up to 9.5 using sodium hydroxide. Aero xanthate 350 and Aerofloat 208 were also added prior to the conditioning period. After the addition of Aerofroth 65, a two minute flotation step followed. Following an additional five minute conditioning stage, Aero xanthate 350 and Aero 208 were added. Aerofroth 65 was added as required. The flotation concentrates were then combined and each flotation product was filtered, dried and prepared for fire assay.

3.6.3 Leaching

A 500 gram sample of the -65 mesh A material was cyanide leached for a period of 72 hours at 50% solids. Leaching was performed in a 2 L pyrex reaction kettle. Agitation was provided by a Caframo variable speed motor and a 3 bladed impellor. The parameters were as follows:

1 gpl NaCN
pH of 10.5

After the leaching period, the pulp was filtered and washed. A sample of the filtrate and wash were submitted for gold analysis. A representative sample of the residue was dried, weighed and prepared for gold fire assay. The remainder of the residue was ground in the ball mill for 20 minutes at 65% solids. The slurry was then releached for 48 hours at 30% solids, 1 gpl NaCN and pH of 10.5. The residue was filtered and washed. Samples of the filtrate, wash and titration solutions were analyzed for gold. The residue was dried and a 200 gram sample was riffled out and prepared for gold fire assay.

A 200 gram sample of the -65 mesh B material was similarly leached in a 400 mL pyrex beaker under the same conditions except that the weight percent solids was 40%.

3.7 Mineralogy

Riffled portions of screen fraction composites were examined using a binocular microscope. All screen fractions from quarter 3 of the A and B samples (hereafter referred to as A-3, B-3) were observed directly following the drying, compositing and riffling procedures. In addition, mineralogical studies were performed on the following:

1. +48 mesh jig concentrate (A-3, B-3)
2. +48 mesh jig tailings (A-3, B-3)
3. +200 mesh table concentrate (A-3, B-3)
4. +200 mesh table tailings (A-3, B-3)
5. +200 mesh vanned concentrate (A-3, B-3 table concentrate)
6. +200 mesh vanned tailings (A-3, B-3 table concentrate)
7. -200 mesh vanned concentrate (A-3, B-3)
8. -200 mesh vanned tailings (A-3, B-3)

The mineralogical studies were utilized to identify gold mineralization, liberation and particle sizes. In addition, the major mineral assemblages were examined and estimates of the mineral distributions are given.

4.0 RESULTS

The results of the test program are summarized in the following sections.

4.1 Head Assays and Analysis

The results of the gold and silver fire assays and the geochemical analyses are given in Table 1.

Table 1

HEAD ANALYSIS

Bulk Sample A (1st Quarter)

Sample	Au (g/t)		Ag (g/t)	Cu %	Zn %	Fe %	As %	S %	Sn %
A-1	< 0.03	0.12	3.5	0.006	0.006	3.19	0.007	0.10	0.015
A-2	< 0.03	< 0.03							
A-3	0.55,	0.25							

Average 0.16 g/t Au

Bulk Sample B (1st Quarter)

Sample	Au (g/t)		Ag (g/t)	Cu %	Zn %	Fe %	As %	S %	Sn %
B-1	0.12,	0.035	2.0	0.006	0.006	3.19	0.007	0.12	0.011
B-2	0.16,	0.029							
B-3	0.26,	0.320							

Average 0.15 g/t Au

Bulk Sample C (1st Quarter)

Sample	Au (g/t)		Ag (g/t)	Cu %	Zn %	Fe %	As %	S %	Sn %
C-1	0.09,	0.10	2.5	0.008	0.006	2.35	0.007	0.21	.0146
C-2	< 0.03	0.051							
C-3	0.044,	0.034							

Average 0.05 g/t Au

4.2 Screen Analysis and Gold Distribution

The results of the screen analyses for the A, B, and C bulk samples are given in Tables 2, 3 and 4, respectively. The gold assays and their relative distribution with the third quarter of the A and B samples, are also indicated in Table 5. Based upon these data, the subsequent testwork was performed on screened fractions of each composite. Recoveries are based upon the test feed, and do not relate directly back to the ore prior to preconcentration.

Table 2

SIZE DISTRIBUTION

BULK SAMPLE A (2nd QUARTER)

	Wt (g)	Wt %	Wt (g)	Au (g/t)	Au (mg)	Au % Dist
+1"	6539	12.80		0.25	1.6348	25.43
+1/2"	5142	10.07		0.03	0.1543	2.40
+1/4"	5643	11.05		0.03	0.1693	2.63
+6M	6290	12.32		0.03	0.1887	2.93
-6M	27455	53.76				
+8M	151.1	9.78	4994.55	0.03	0.1498	2.33
+10M	160.0	10.36	5290.75	0.03	0.1587	2.47
+14M	110.5	7.15	3651.43	0.03	0.1095	1.70
+20M	49.5	3.20	1634.20	0.03	0.0490	0.76
+28M	30.5	1.97	1006.06	0.03	0.0302	0.47
+35M	24.5	1.59	812.00	0.13	0.1056	1.64
+48M	64.6	4.19	2139.79	0.10	0.2140	3.33
+65M	96.4	6.24	3186.71	0.05	0.1593	2.48
+100M	118.5	7.67	3916.99	0.80	3.1336	48.75
+150M	21.7	1.41	720.07			
+200M	2.1	0.14	71.50			
+270M	0.5	0.03	15.32	0.21	0.1726	2.68
+325M	-	-	-			
-325M	0.5	0.03	15.32			
	51069.0	100.00			6.4294	100.00

Calculated Head - 0.13 g/t Au

Table 3

SIZE DISTRIBUTION

BULK SAMPLE B (2nd QUARTER)

	Wt (g)	Wt %		Au (g/t)	Au (mg)	Au % Dist
+1"	4278	7.08		0.11	0.4706	9.05
+1/2"	4745	7.86		0.05	0.2373	4.56
+1/4"	4816	7.97		0.05	0.2408	4.63
+6M	8070	13.36		0.10	0.8070	15.52
-6M	38491	63.73				
			Wt (g)			
+8M	166.9	10.07	6082.28	0.03	0.1825	3.51
+10M	146.6	8.85	5345.40	0.03	0.1604	3.08
+14M	111.0	6.70	4046.80	0.03	0.1214	2.33
+20M	171.9	10.37	6263.48	0.03	0.1880	3.61
+28M	118.1	7.13	4306.52	0.03	0.1292	2.48
+35M	184.4	11.13	6722.52	0.03	0.2017	3.88
+48M	117.9	7.12	4300.48	0.03	0.1290	2.48
+65M	22.0	1.33	803.32	0.03	0.0241	0.46
+100M	9.4	0.57	344.28			
+150M	3.7	0.22	132.88			
+200M	1.8	0.11	66.44	3.69	2.3090	44.41
+270M	1.1	0.07	42.28			
+325M	0.1	0.006	3.62			
-325	1.0	0.06	36.24			
	60400.0	100.0			5.2010	100.00

Calculated Head 0.09 g/t Au

Table 4

SIZE DISTRIBUTION

BULK SAMPLE C (2nd QUARTER)

	Wt (g)	Wt %		Au (g/t)	Au (mg)	Au % Dist
+1"	2704	3.90		0.27	0.7301	25.35
+1/2"	14940	21.54		0.04	0.5976	20.75
+1/4"	14181	20.44		0.03	0.4254	14.78
+6M	5562	8.02		0.03	0.1669	5.80
-6M	31981	46.10				
			Wt (g)			
+8M	46.9	2.24	1553.84	0.03	0.0466	1.62
+10M	41.5	1.98	1373.49	0.03	0.0412	1.43
+14M	39.8	1.90	1317.99	0.03	0.0395	1.37
+20M	33.3	1.59	1102.95	0.03	0.0331	1.15
+28M	41.5	1.98	1373.49	0.03	0.0412	1.43
+35M	66.4	3.17	2198.97	0.03	0.0660	2.29
+48M	214.6	10.24	7103.28	0.03	0.2131	7.40
+65M	257.6	12.29	8525.33	0.03	0.2558	8.88
+100M	210.4	10.04	6964.55	0.03	0.2089	7.25
+150M	11.8	0.56	388.46			
+200M	1.2	0.06	41.62			
+270M	0.5	0.02	13.87	0.03	0.0143	0.50
+325M	0.1	0.005	3.47			
-325M	0.8	0.04	27.75			
	69368.0	100.0			2.8797	100.00

Calculated Head 0.04 g/t Au

Table 5

Au DISTRIBUTION

Bulk Sample A (3rd Quarter)

	Wt (kg)	Wt %	Au (g/t)	Au (mg)	Au % Dist.
+ 8 mesh	27.0	56.6	0.14	3.78	41.3
- 8, +48 mesh	13.4	28.0	(0.28) *	(3.75) *	40.9
-48, +200 mesh	7.3	15.3	(0.19) **	(1.39) **	15.2
-200 mesh	0.05	0.1	4.81	0.24	2.6
Total	47.75	100.0	(0.19)	9.16	100.0

Bulk Sample B (3rd Quarter)

	Wt (kg)	Wt %	Au (g/t)	Au (mg)	Au % Dist
+ 8 mesh	29.09	47.84	0.11	3.20	30.1
- 8, +48 mesh	30.45	50.08	(0.20) *	(6.09) *	57.3
-48, +200 mesh	1.17	1.92	(0.71) **	(0.83) **	7.8
-200 mesh	0.10	0.16	5.09	0.51	4.8
Total	60.81	100.0	(0.17)	10.63	100.0

* Calculated from results of Jig Tests
** Calculated from results of Table Tests

4.3 Gravity Concentration

4.3.1 Jigging Testwork

The results of the jigging testwork are summarized in Tables 6, 7 and 8. Jigging evaluation was conducted on the third quarter of both A and B samples (Tables 6, 7). The -8, +48 mesh fraction was used as feed material for the jig. Due to the anomalous gold assay results of the jig concentrates of the A sample, a second jigging test was performed (Table 8). A jig test was conducted on the -28, +65 mesh material from quarter four of the A sample (Table 8).

This test did not confirm the results of the jig test completed on the third quarter of bulk sample A. This was likely due to the very spotty gold content of the various samples in the coarser size fractions.

Table 6

JIG TEST SUMMARIES

Test - 1- Bulk Sample A, 3rd quarter

Product	Mass Balance Wt (g)	Mass Balance Au (g/t)	Mass Balance Au (mg)	Distribution Wt %	Distribution Au %
Jig Conc.	8.1	82.06	0.0821	0.35	12.39
Jig Bed	184.0	0.12	0.0221	7.87	3.34
Jig Tails	2146.8	0.26	0.5582	91.78	84.27
Feed	2338.9	(0.28)	0.6624	100.00	100.00

Test - 2 Bulk Sample A, 3rd quarter

Product	Mass Balance Wt (g)	Mass Balance Au (g/t)	Mass Balance Au (mg)	Distribution Wt %	Distribution Au %
Jig Conc.	9.8	0.46	0.0045	0.40	3.21
Jig Bed	180.4	0.12	0.0216	7.31	15.42
Jig Tails	2279.1	0.05	0.1140	92.29	81.37
Feed	2469.3	(0.06)	0.1401	100.00	100.00

JIG TEST SUMMARIES

Table 7

Test - 3 Bulk Sample B, 3rd Quarter

	Mass Balance			Distribution	
Product	Wt (g)	Au (g/t)	Au (mg)	Wt %	Au &
Jig Conc.	24.7	4.61	0.1139	1.23	27.90
Jig Bed	168.3	0.13	0.0219	8.38	5.36
Jig Tails	1816.5	0.15	0.2725	90.39	66.74
Feed	2009.5	(0.20)	0.4083	100.00	100.00

JIG TEST SUMMARIES

Table 8

Test - 4 Bulk Sample A, 4th Quarter

	Mass Balance			Distribution	
Product	Wt (g)	Au (g/t)	Au (mg)	Wt %	Au %
Jig Conc.	304.13	0.03	.009	3.54	0.55
Jig Bed	134.4	0.03	.004	1.56	0.24
Jig Tails	8164.0	0.20	1.633	94.90	99.21
Feed	8602.53	(0.19)	1.646	100.0	100.0

4.3.2 Tabling

The results of the Deister Table testwork are summarized in Table 9. The quarter 3, A and B samples were tabled with the sand deck while the quarter 4 A sample was tabled using the slimes deck. The quarter 4 table concentrate recovered 78.4% of the gold from the table feed.

Based on this preliminary work, it appears that the slime deck was much more successful in producing an upgraded product.

4.3.3 Vanning

The results of the vanning tests on the quarter 3 A and B -200 mesh material and the quarter 4 B -65 mesh material are summarized in Table 10. The best results were obtained from quarter 4 when the -65 mesh material was concentrated using a vanning plaque. A higher weight concentrate was obtained in this test. The gold recovered from this fraction was 94.7%. Mineralogical examinations were performed on all products.

4.4 Flotation

The results of the flotation testwork are summarized in Table 11. Test conditions are summarized in Appendix I. The results from sample B of the 4th quarter show that 58.9% of the gold was recovered into 3.67% of the feed weight. The feed was -65 mesh in size.

4.5 Leaching

The cyanidation leach test summaries are given in Table 12 and additional data in Appendix I. The mass balances for A-4-2 and for B-4-3 and B-4-4 were not calculated due to low gold values and lack of available sample, respectively. Indicated extraction in each of the tests was greater than 90%. The gold was therefore amenable to leaching.

The anomalous residue in test B-4-3 results in a very poor gold mass balance for test B-4-4. As a result of the small amount of sample, the test could not be re-run. For evaluation purposes, test B-4-3 was recalculated using the calculated head value from test B-4-4 as the B-4-3 calculated residue. In tests A-4-1 and A-4-2, (leaching directly followed by grinding and re-leaching) the result was no additional recovery in the second leach.

TABLE TEST SUMMARIES

Table 9

Test - 1 Bulk Sample A 3rd quarter -48, +200 Mesh Material (Sand Deck)

	Mass Balance			Distribution	
Product	Wt (g)	Au (g/t)	Au (mg)	Wt %	Au %
Table Conc.	404.6	0.56	0.2266	5.55	16.23
Table Tails	6879.6	0.17	1.1695	94.45	83.77
Feed	7284.2	(0.19)	1.3961	100.00	100.00

Test - 2 Bulk Sample B - 3rd Quarter -48, +200 Mesh Material (Sand Deck)

	Mass Balance			Distribution	
Product	Wt (g)	Au (g/t)	Au (mg)	Wt %	Au %
Table Conc.	192.2	2.24	0.4305	16.44	51.81
Table Tails	976.6	0.41	0.4004	83.56	48.19
Feed	1168.8	(0.71)	0.8309	100.00	100.00

Test - 3 Bulk Sample A - 4th Quarter -65 Mesh Material (Slime Deck)

	Mass Balance			Distribution	
Product	Wt (g)	Au (g/t)	Au (mg)	Wt %	Au %
Table Conc.	349.0	1.28	0.4467	7.85	78.42
Table Tails	4097.0	0.03	0.1229	92.15	21.58
Feed	4446.0	(0.13)	0.5696	100.00	100.00

Table 10

VANNING TEST SUMMARY

Test - 1 Bulk Sample A - 3rd Quarter -200 Mesh Material

	Mass Balance			Distribution	
Product	Wt (g)	Au (g/t)	Au (mg)	Wt %	Au %
Van Conc.	1.05	46.67 (calc)	0.0490	2.75	26.66
Van Tail	37.4	3.63	0.1348	97.25	73.34
Feed	38.19	4.81	0.1838	100.00	100.00

Test - 2 Bulk Sample B - 3rd Quarter -200 Mesh Material

	Mass Balance			Distribution	
Product	Wt (g)	Au (g/t)	Au (mg)	Wt %	Au %
Van Conc.	.97	283.48 (calc)	0.2750	1.37	76.45
Van Tail	69.69	1.215	0.0847	98.63	23.55
Feed	70.66	5.09	0.3597	100.00	100.00

Test - 3 Bulk Sample B 4th quarter -65 Mesh Material

	Mass Balance			Distribution	
Product	Wt (g)	Au (g/t)	Au (mg)	Wt %	Au %
Van Conc.	9.95	59.3	0.5900	10.55	94.72
Van Tail	84.32	.39	0.0329	89.45	5.28
Feed	94.27	6.61	0.6229	100.00	100.00

FLOTATION TEST SUMMARIES

Test 1 - Bulk Sample A - 4th Quarter

	Mass Balance			Distribution	
Product	Wt. (g)	Au (g/t)	Au (mg)	Wt. %	Au %
Conc.	1.8321	58.7	0.1075	0.35	30.7
Tails	526.5	0.46	0.2422	99.65	69.3
Feed	528.33	(0.66)	0.3497	100.00	100.0

Flotation Test 2 - Bulk Sample B - 4th Quarter

	Mass Balance			Distribution	
Product	Wt. (g)	Au (g/t)	Au (mg)	Wt. %	Au %
Conc.	6.8659	148.6	1.0203	3.57	58.96
Tails	185.4	3.83	0.7101	96.43	41.04
Feed	192.27	(9.00)	1.7304	100.00	100.00

Table 12

CYANIDATION LEACH TEST SUMMARIES

Test No.	Time Hrs.	pH	Grind Min.	Consumption kg/t NaCN	Consumption kg/t Lime	Residue g/t Au	Calc.Head g/t Au	Extraction % Au	Mass Bal. %
A-4-1	72	10.5	-	2.96	1.86	0.03	0.33	91.02	118
A-4-2 **	48	10.5	20	1.28	0.6	0.03	0.03	0.03	-
Total	120	-	20	4.24	2.46	0.03	0.33		
B-4-3	72	10.5	-	3.05	4.8	5.75	7.65	87.7	-
B-4-4 **	48	10.5	20	1.75	1.4	0.03	(0.94)	94.1	-
Sub Total								99.0	
Total	120	-	20	4.8	6.2		12.23		

* Indicates less than 0.03 g/t Au

** Test A-4-2 performed on residue of A-4-1
Test B-4-3 performed on residue of B-4-3

4.6 Mineralogy

The results of the mineralogical studies are as follows:

1. A-3 +48 mesh jig concentrate

   The sample contained elongated to subrounded, locally angular, frosted grains consisting of quartzo-feldspathic material, epidote-feldspathic grains, garnetiferous and micaceous metasediments and various reddish hematitic metasediments. White micas and magnetite formed a minor component.
   - sulfide mineralization was absent
   - gold mineralization was not observed

2. A-3 +48 mesh jig tailings

   The sample contained abundant subrounded to subangular granitoids and schistose feldspathic to quartoze particles with lesser angular fragments of quartz, feldspar, epidote, white mica, dark red garnet, hematite and magnetite.
   - sulfide mineralization was absent
   - gold mineralization was not observed

3. A-3 +200 mesh table concentrate

   The sample contained primarily quartzofeldspathic grains, angular to subrounded quartz and partially replaced feldspars with minor component of translucent reddish pink garnet. Lesser quantities included ferromagnesians, magnetite, ilmenite, biotite, muscovite and granitoid rock fragments.
   - sulfide mineralization not observed
   - gold mineralization not observed

4. **A-3 +200 mesh table tailings**

The sample contained approximately 60-70% quartz and feldspar particles, with lesser angular to subrounded frosted rock fragments of varied provenance (sedimentary, granitoid, gneissic), minor epidotized grains, muscovite and biotite, magnetite and ilmenite are generally rare. Garnets, of the reddish to translucent varieties are absent.

- sulfide mineralization consisted of rare, subhedral to angular pyrite particles
- gold mineralization was not observed

5. **A-3 +200 mesh vanned concentrate (from table concentrate)**

The sample contained approximately 50-60% of dark grey to black ferromagnesians and iron oxides, primarily magnetite and hematite with lesser specularite. Some secondary iron oxides-hydroxides were present. Ferromagnesians are locally locked into granitoid, gneissic and varied rock fragments. The remaining 40-50% comprised light coloured, lower density phases primarily quartz, feldspathic particles and pale red to translucent garnets with minor white mica.

- sulfides occurred as rare subhedral to angular particles of pyrite and possible arsenopyrite
- gold mineralization was not observed.

6. **A-3 +200 mesh van tailings (from table concentrate)**

The sample contained primarily quartz, feldspathic grains and nonferromagnesian rock fragments, minor garnets, and few chloritized ferromagnesian minerals, minor magnetite and specularite.

- sulfides were rare and comprised minute angular particles of pyrite and chalcopyrite
- gold mineralization was not observed

7. A-3 -200 mesh vanned concentrate

The sample was typified by angular to euhedral particles of quartz and epidotized quartzofeldspathic rock fragments subordinate to ferromagnesian rock fragments and iron oxides. Angular to subhedral magnetite-ilmenite and hematite-specularite are common. Minor particles of white mica, biotite and garnet were present.

- sulfide mineralization comprised few angular pyrite particles
- gold mineralization was not observed

8. A-3 -200 mesh vanned tailings

The sample contained primary angular clays, micas, and quartzofeldspathic material. Minor components of quartz crystals, and very fine oxides were present.

- sulfides comprised rare, very fine particles of pyrite
- gold mineralization was not observed

9. B-3 +48 mesh jig concentrate

The sample contained angular to subrounded particles of varied provenance including schistose and massive quartzofeldspathic grains, and igneous to gneissic rock fragments. Pale coloured translucent garnets were common. Numerous iron oxides, magnetite, hematite and specularite are present.

- minor sulfides include angular particles of pyrite
- gold mineralization was not observed

10. B-3 +48 mesh jig tailings

The sample comprised a strongly mixed provenance of granitoid, gneissic, schists and metasediments with a low component of quartz and feldspar particles. A minor component of iron oxides and feromagnesian rock fragments was observed.

- sulfide mineralization was absent
- gold mineralization was not observed

11. B-3 +200 mesh table concentrate

The sample consists primarily of four mineral assemblages including calcic garnets, magnetite-hematite, quartzofeldspathic grains, and ferromagnesian with rock fragments as a minor component. The garnets are typically subhedral, pale pink and typically display clear, unfrosted crystal faces. Quartz feldspathic material includes euhedral to subhedral prismatic quartz crystals and frosted rock fragments. Ferromagnesians are commonly altered to chlorite. Gneissic sedimentary and granitoid rock fragments are spherical to oblate and form the coarser particles.

- sulfides include a minor component of angular pyrite particles.
- gold mineralization was not observed

12 B-3 +200 mesh table tailings

The sample comprised abundant quartz feldspathic rock fragments, typically angular and frosted; various frosted rock fragments and a very minor component of garnet and iron oxides.

- sulfides include pyrite which forms angular free particles and midling associations with quartz
- gold mineralization was not observed

13. B-3 +200 mesh vanned concentrate (from table concentrate)

The sample consisted primarily of 30-35% pink translucent garnet, 40% fine magnetite and hematite (speculatite) and 10-15% ferromagnesian silicates. Minor components include quartzofeldspathic particles (5-10%) rock fragments (5%)

- minor sulfide mineralization was dominated by very fine angular pyrite
- gold mineralization was not observed

14. B-3 -200 mesh vanned tailings (from table concentrate)

The sample was primarily a mixture of quartz, feldspar, rock fragments (typically nonferromagnesian) of angular to subrounded forms and frosted surfaces. Minor garnets and chloritic ferromagnesians were present.

- minor particles of pyrite were observed
- gold mineralization was not observed

15. B-3 -200 mesh vanned concentrate

The sample was typified by fine to very fine particles of ferromagnesians, magnetite, hematite, with minor components of quartzofeldspathic material.

- sulfides consisted of rare angular pyrite
- gold mineralization was observed as a coarse 70-75 micron, irregular, winglike placer particle with smooth grain boundaries

16. B-3 -200 mesh vanned tailings

The sample consisted primarily (95%) of quartz crystals and quartzofeldspathic particles and slimes with a very minor component of ferromagnesians and oxides.

- sulfides comprised angular pyrite particles
- gold mineralization was not observed

5.0 COMMERCIAL PROCESSING METHODS

Due to the very low grade of the placer material, a simple flowsheet must be selected which is capable of handling 40,000-80,000 tons per day of placers. Crushing, grinding and processing the coarse fractions to recover gold from any of the fractions will not be economical.

Based on the results of the metallurgical testing, a conventional placer approach utilizing trommells, screens and gravity upgrading equipment may be feasible. This type of circuit could be very economical if the tonnage throughput is high enough. Based on the testing, it is estimated that a gold recovery of 30-35% should be used for preliminary economics (i.e. 65% x 50% = 32.5%). Fifty percent of the gold is lost with 95% of the weight rejected in preconcentration.

Reichart spirals are the first choice for the gravity upgrading equipment. These spirals can handle fine material. They are compact, and the only energy requirement is the pumping equipment. This makes them an ideal choice for on-board processing. Reichart spirals are currently being utilized in other placer applications. Comparative experience with tables vs spirals suggests that the spiral be tested further. Only after further testing, using a larger test sample and the appropriate equipment, can a final flowsheet be set for good economic evaluation.

Technical data for the spiral, and typical flowsheet descriptions are presented in Appendix II.

6.0 CONCLUSIONS

1. Preconcentration was successfully accomplished by screening the placer material at 65 mesh. The placer grades of 0.09 - 0.16 g/t were upgraded to 0.7 - 3.69 g/t by rejecting the +65 mesh portion of the placer material.

2. Gravity concentration by jigging did not produce favourable results as the gold is most likely too fine to be efficiently recovered by a jig. Gravity concentration using a table however proved to be more favourable, producing upgrading of ten times in one stage when the slimes deck was used.

3. Flotation testing indicated that flotation would yield better recoveries than jigging, and similar to tabling. Flotation however would be capital intensive and could not be carried out on board.

4. Leaching of the -65 mesh fraction indicated that a good recovery, well in excess of 90%, would result by conventional cyanidation. Cyanide consumptions were high considering the low head grades. However, this work showed that the gold was amenable to cyanidation and that high grade concentrates could be cyanided on shore for dore production.

5. Pilot scale testing on large bulk samples to produce a larger amount of concentrate and confirm recovery numbers is necessary to evaluate the project further.

7.0 RECOMMENDATIONS

1. Obtain a 20 tonne sample of placer gravel for further testing to prove the flowsheet, confirm the recoveries and to produce concentrate for further upgrading tests.

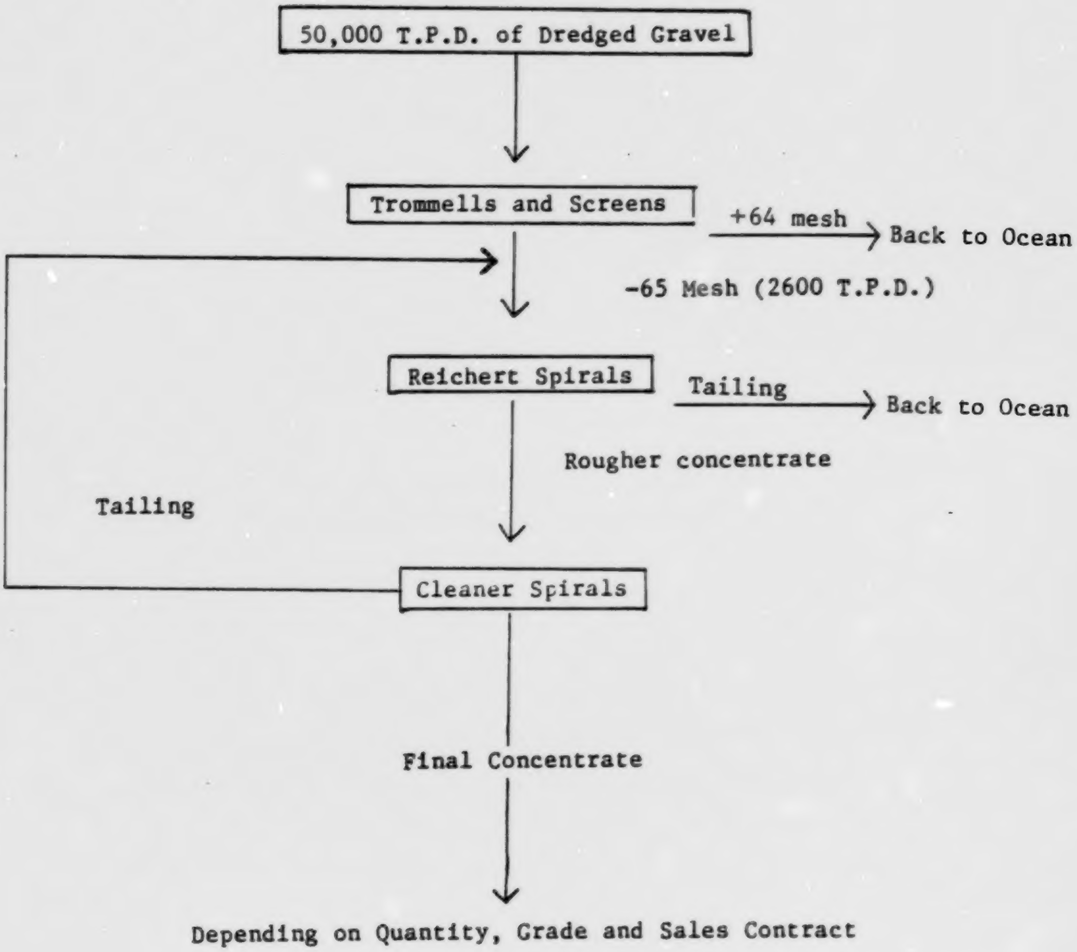
2. Test the proposed flowsheet (Figure 4) by screening to -65 mesh, using Reichert spirals to make a final gravity concentrate. Emphasis should be placed on the cleaning stages to produce a high grade concentrate.

3. Determine the recovery that can be obtained by cyanide leaching of the highest possible grade of concentrate, with and without grinding.

4. Evaluate the alternatives that exist for capital equipment as a trade-off against recovery. Net smelter returns from concentrate sales should be compared to concentrate cyanidation and dore sales.

Figure 4

PROPOSED FLOWSHEET


50,000 T.P.D. of Dredged Gravel
Trommells and Screens
+64 mesh
Back to Ocean
-65 Mesh (2600 T.P.D.)
Reichert Spirals
Tailing
Back to Ocean
Rougher concentrate
Tailing
Cleaner Spirals
Final Concentrate
Depending on Quantity, Grade and Sales Contract

Option 1	Option II
- Ship to smelter	- Further treatment onshore (ie cyanide leaching of gravity concentrates)
- Concentrate Sales	- Dore sales

APPENDIX I

TEST SUMMARY SHEETS

WITTECK DEVELOPMENT INC. FLOTATION TEST REPORT

SAMPLE: Nordco A - 4 - 65 Mesh WEIGHT-GR: 500 TEST NO: 1

PURPOSE:

DATE: May 2, 1986

TEST BY: Chris Bever

Operation	TIME Min.	% Solids	pH	Unit	rpm	reagent kg/t		
						Aero 350	Aero 208	Frother 65
Condition	5	30	9.5	500 gram cell	1200	.05	.05	.05
Float	2	30	9.5	500 gram cell	1200			
Condition	2	30	9.5	500 gram cell	1200	.05	.05	.05
Float	10	30	9.5	500 gram cell	1200			
TOTAL						.10	.10	.10

0637A

WDI

WITTECK DEVELOPMENT INC. FLOTATION TEST REPORT

SAMPLE: Nordco B - 4 -65 mesh WEIGHT-GR: 200 TEST NO: 2

PURPOSE: DATE: May 2, 1986

TEST BY: Chris Bever

Operation	TIME Min.	% Solids	pH	Unit	rpm	reagent kg/t		
						Aero 350	Aero 208	Frother 65
Condition	5	30	9.5	250 gram cell	1200	.06	.06	.06
Float	2	30	9.5	250 gram cell	1200			
Condition	2	30	9.5	250 gram cell	1200	.06	.06	.06
Float	10	30	9.5	250 gram cell	1200			
TOTAL						.12	.12	.12

0637A

WDI

CYANIDATION LEACH SUMMARY

TEST NO. : 1

PURPOSE :

FEED : 506.4 grams of Nordco A-4 -65 Mesh

GRIND : - minutes; 65 % solids

PREAERATION : hours % solids

LEACH : 72 hours; 40 % solids

REPULP :

WASH : 5 x 200 mls water - twice solids weight

REAGENTS : Grind -
Preaeration -
Leach - NaCN : 1 g/l ; Lime : 10.5 pH+

CONSUMPTIONS (kg/t) NaCN: 2.96 Lime: 1.86 Pb Nitrate.:

MASS BALANCE

Product	WT/VOL g/ml	Au ppm	Au mg	% Au Dist'n
Grind				
Filtrate 1	575	0.21	0.12	72.29
Wash	1000	0.02	0.02	11.97
Titration	565	0.02	0.01	6.76
Residue	499.8	<0.03	0.01	8.98
Total			0.16	100.00

Au EXTRACTION : 91.02 % CALC. HEAD : 0.32 g/t
ASSAYED HEAD : .27 g/t MASS BALANCE : 118 %

Comments :

CYANIDATION LEACH SUMMARY

TEST NO. : 2

PURPOSE : Repulp of Test 1 residue

FEED : 500 grams of Nordco A-4 -65 Mesh Fraction

GRIND : 20 minutes; 65 % solids

PREAERATION : hours % solids

LEACH : 48 hours; 50 % solids

REPULP :

WASH : 5 x 200 mls water - twice solids weight

REAGENTS : Grind -
Preaeration -
Leach - NaCN : 1 gpl ; Lime : 10.5

CONSUMPTIONS (kg/t) NaCN: 1.28 Lime: .6

MASS BALANCE

Product	WT/VOL g/ml	Au ppm	Au mg	% Au Dist'n
Grind Filtrate 1	470	<0.03	0.0	
Wash	1030	<0.03	0.0	
Titration	605	<0.03	0.0	
Residue	476.4	<0.03	0.0	
Total			0.0	100.00

Au EXTRACTION : %
ASSAYED HEAD : g/t
CALC. HEAD : 0.03 g/t
MASS BALANCE : %

Comments :

CYANIDATION LEACH SUMMARY

TEST NO. : 3

PURPOSE : First leach test

FEED : 206.1 grams of Nordco B-4 -65 Mesh

GRIND : - minutes; 65 % solids

PREAERATION : - hours - % solids

LEACH : 72 hours; 40 % solids

REPULP :

WASH : 5 x 100 mls water - twice solids weight

REAGENTS : Grind -
Preaeration -
Leach - NaCN : 1 g/l ; Lime : 10.5 pH+

CONSUMPTIONS (kg/t) NaCN: 3.05 Lime: 4.8 Pb Nitrate.:

MASS BALANCE

Product	WT/VOL g/ml	Au ppm	Au mg	% Au Dist'n
Grind	300	4.12	1.24	80
Filtrate 1	500	0.21	0.11	7.1
Wash				.6
Titration	550	0.02	0.01	
Residue	202.6	(.94)	0.19	12.3
Total		7.65	1.55	100.00

Au EXTRACTION : 87.7 % CALC. HEAD : 7.65 g/t
ASSAYED HEAD : g/t MASS BALANCE : %

Comments :

CYANIDATION LEACH SUMMARY

TEST NO. : 3

PURPOSE :

FEED : 206.1 grams of Nordco B-4 -65 Mesh

GRIND : - minutes; 65 % solids

PREAERATION : - hours - % solids

LEACH : 72 hours; 40 % solids

REPULP :

WASH : 5 x 100 mls water - twice solids weight

REAGENTS : Grind -
Preaeration -
Leach - NaCN : 1 g/l ; Lime : 10.5 pH+

CONSUMPTIONS (kg/t) NaCN: 3.05 Lime: 4.8

MASS BALANCE

Product	WT/VOL g/ml	Au ppm	Au mg	% Au Dist'n
Grind				
Filtrate 1	300	4.12	1.24	49.2
Wash	500	0.21	0.11	4.4
Titration	550	0.02	0.01	.4
Residue	202.6	5.75*	1.16	46.0
Total			2.52	100.00

Au EXTRACTION : 54.0 % CALC. HEAD : 12.23 g/t
ASSAYED HEAD : g/t MASS BALANCE : %

Comments:

* assayed, but appears anomalously high; this mass balance was not used, but is only included for completeness.

CYANIDATION LEACH SUMMARY

TEST NO. : 4

PURPOSE :

FEED : 180 grams of Nordco B-4 -65 Mesh Fraction

GRIND : 20 minutes; 65 % solids

PREAERATION : - hours - % solids

LEACH : 48 hours; 50 % solids

REPULP :

WASH : 5 x 100 mls water - twice solids weight

REAGENTS : Grind -
Preaeration -
Leach - NaCN : 1 gpl ; Lime : 10.5 pH+

CONSUMPTIONS (kg/t) NaCN: 1.75 Lime: 1.4

MASS BALANCE

Product	WT/VOL g/ml	Au ppm	Au mg	% Au Dist'n
Grind				
Filtrate 1	350	0.33	0.12	70.5
Wash	495	0.05	0.02	11.8
Titration	505	0.03	0.02	11.8
Residue	179.8	< 0.03	0.01	5.9
Total			0.17	100.00

Au EXTRACTION : > 94.1 % CALC. HEAD : 0.94 g/t
ASSAYED HEAD : 5.75 g/t MASS BALANCE : %

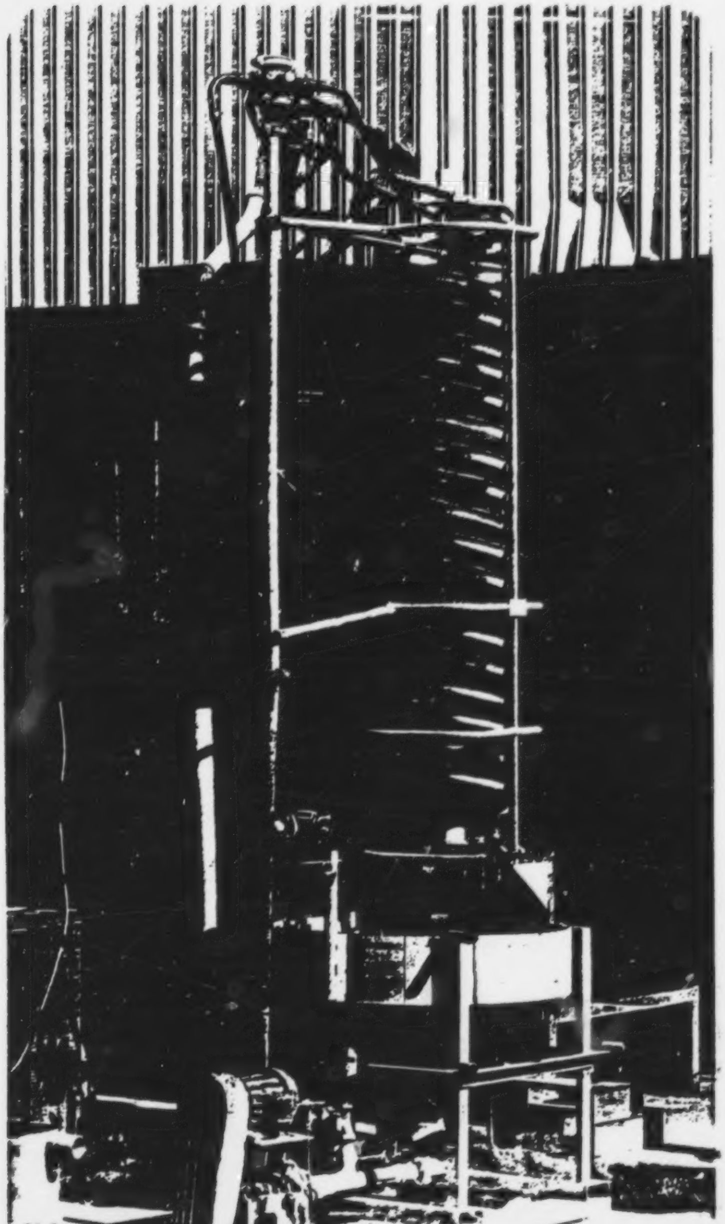
Comments :

APPENDIX II

REICHERT SPIRAL INFORMATION

MINERAL DEPOSITS LIMITED

Head Office: 81 Ashmore Road,
Southport, Qld. 4215, Australia
Postal Address: P.O. Box 5044, Gold
Coast Mail Centre, Australia, 4217.
Telephone: (075) 39 9055
Cables: Mindeposit, Southport,
Queensland.
Telex: 40438



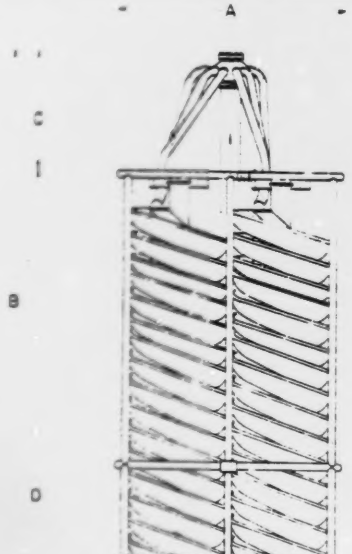
UNIQUE INTERLOCKING RECEIVERS

MARK VII SPLITTER ARRANGEMENT

REICHERT MK VII SPIRAL CONCENTRATOR

FEATURES

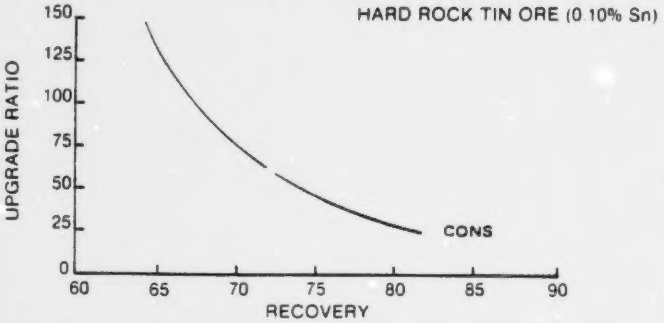
- excellent metallurgical performance without wash-water addition
- single, twin or triple starts per column
- simple operation with only one set of splitters per spiral start
- ganged splitters on multi-start spirals
- water splitter for removing water fraction with minimal solids contact as standard
- single set of product outlets for cons, mids, tails and water splits even on triple start spiral
- constructed in strong, lightweight fibreglass with polyurethane covering and castings for corrosion and abrasion resistance
- product launders available as accessories
- suitable for low grade ores including:
    - mineral sands
    - glass sands
    - tin ores
    - gold ores
    - tungsten ores
    - tantalum/niobium ores
    - chromite sands
- test facilities available throughout the world

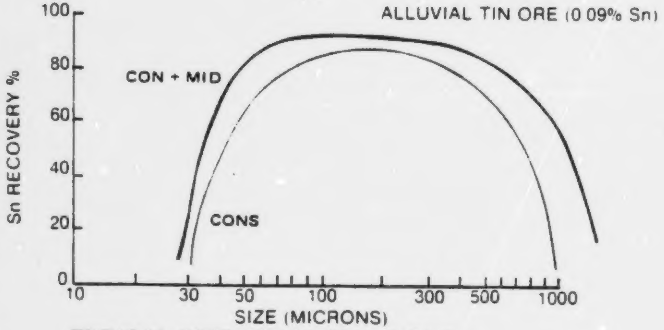


Reichert Mark VII Spiral Concentrator

MINERAL DEPOSITS LIMITED

TYPICAL UP-GRADE RATIO VERSUS RECOVERY CURVE





TYPICAL SIZE RECOVERY CURVE

DESIGN DATA

HEAD FEED (PER START)

Capacity:	up to 3TPH solids depending on application
Pulp Density (w/w):	up to 60% solids
Size Range:	0.03 - 2mm
Pulp Volume (max.):	5.0 m³/hr.

CONCENTRATE REMOVAL (PER START)

Rate:	up to 0.3TPH solids
Pulp Density:	30-60% solids w/w.

NOTE: SINGLE, TWIN, TRIPLE STARTS AVAILABLE.

DIMENSIONS IN SPIRAL BANKS

(Refers to double row banks, single row available)

SPIRALS PER BANK	DIMENSIONS IN MILLIMETRES				INSTALLED WEIGHT (Kgs) (See note below)
	A	B	C	D	
2	740	3940	700	3240	290
4	1350	3940	700	3240	540
6	1975	4080	840	3240	820
8	2600	4080	840	3240	1035

NOTE: Weight refers to Triple Start Spirals.

DIMENSIONS: Use dimensions as guide only. Certified drawings will be provided on receipt of order. All dimensions in millimetres.

SHIPPING DETAILS: Spiral banks, except two spiral unit, are packed for shipment mounted on a wooden pallet 100mm (4") high. Ancillary equipment is packed in separate containers. The two spiral unit with ancillaries is packed in a wooden crate. Single spirals are shipped in tri-wall containers.

GOLD PLACER OPERATIONS
IN
NORTH AMERICA
USING
REICHERT SPIRALS

by
Clifford N. Robinson
and
Kelly Dolphin

Fourth Annual RMS-ROSS Seminar
on
PLACER GOLD MINING
Vancouver, British Columbia, Canada
February 6-9, 1984

SYNOPSIS

In the last 12 months since the 1983 RMS-ROSS Seminar, Mineral Deposits Limited and their agents have placed the equivalent of 250 single-start Reichert Mark-7 Spiral Concentrators in North American gold operations.

These spirals are currently operating in 16 states of the USA, 2 Canadian Provinces and Mexico. Additionally a number of extensive testwork programs have been completed and major gold projects are currently under consideration.

In addition to the above installations, Reichert Mark-7 Spirals have been sold in seven other countries on four continents.

This paper is concerned with gold placer operations in Alaska, Arizona, California and Idaho.

LYNX CORPORATION OF NEVADA

This plant is situated at Prescott Valley, Arizona approximately 100 road miles due north of Phoenix. The deposit consists of a relatively recent river bed that was mined by dredging around the early 1900's.

Present mining uses pan scrappers in the loose gravels (old dredge tailings) when dry conditions allow. When wet conditions prevail back hoes are used to load 50 ton dump trucks.

The trucks dump at the rate of 200 cubic yards/hour onto a grizzly with 8" grids into a bin. A conveyor carries the minus 8" material into a 65 foot long X 9 foot diameter scrubber/trommel with 2" screen openings. Heavy duty water spray bars are located throughout the length of the scrubber/trommel assembly.

The plus 2" oversize is collected in a storage bin and back loaded to the mined areas. The minus 2" material is conveyed to a vibrating double deck screen with 3/8" and 20 mesh decks.

Plus 3/8" material is conveyed back to the reject oversize storage bin and dumped. Minus 3/8" plus 20 mesh material is treated on 4 double hutch mineral jigs in parallel with the jig tailings passing over a 3/16" curved screen and the oversize conveyed to the reject storage bin, and the undersize pumped to the water reclaimation pond.

Jig concentrate is batch treated in two stages of Knudson Bowls with first stage Knudson tailing feeding the second stage to produce two coarse gold concentrate fractions.

The minus 20 mesh screen undersize is pumped to a 24" Linatex Hydrocyclone Separator with the overflow reporting to the water reclaim pond and the underflow feeding a Dings double drum wet magnetic separator (72" long X 30" diameter). The magnetics (magnetite) is stockpiled and the non-magnetics (approximately 40 TPH) are pumped to 8 triple-start Reichert Mark-7 Spiral Concentrators.

The primary spiral concentrate gravity feeds to 4 single-start Reichert Mark-7 Spiral Concentrators. The primary spiral tailings plus middlings are pumped to the water reclaim pond. The secondary spiral tailings plus middlings are returned to the primary spirals and the secondary spiral concentrate is processed through two stages of Knudson Bowls to produce two fine gold concentrate fractions.

Alternatively the first stage Knudson Bowl tailing has been run through a Mill Spex Spiral Concentrator with the Mill Spex tailings running down an 8 foot sluice consisting of Astro Turf. The concentrates from the Knudson Bowl, Mill Spex and Sluice then constitute the fine gold concentrate.

No definative plant testing program has been established, but indications from random sampling of the spiral circuit indicates a plus 85% recovery of fine gold is being achieved.

HANSEN BROTHERS ENTERPRISES

This plant, known as the Greenhorn Project is situated at Grass Valley, California on the Greenhorn River approximately 75 road miles north east from Sacramento.

The Reichert Spiral plant will recover fine gold from 200 TPH of minus 3/8" fine gravel out of the back end of the present gravel operation. Due to a teamsters strike this plant has been sitting idle for the last 6 months.

The 200 TPH of minus 3/8" gravel will be fed to a vibrating primary screen to reject approximately 50% of the sand as plus 1/4" reject material, which will be gravity fed to an Eagle Iron Works sand screw and stockpiled.

The minus 1/4" screen undersize material will gravity feed a 16 mesh DSM-type screen with the oversize product being pumped to the sand screw and stockpiled.

The DSM undersize product will then be pumped to a Linatex Hydrocyclone Separator with the overflow product reporting to a settling pond. The hydrocylone underflow product will gravity feed a Dings double drum wet magnetic separator with the magnetics (magnetite) reporting to the sand screw or stockpiled separately.

The non-magnetics product (approximately 75 TPH) will be pumped to a bank of 12 triple-start Reichert Mark-7 Spiral Concentrators. Primary spiral tailings will gravity feed to the sand screw; middlings will be recycled to primary spiral head feed; and concentrate will be gravity fed to 2 single-start Reichert Mark-7 Cleaner Spiral Concentrators.

Cleaner spiral concentrate will be drummed and go to a gold recovery room and middlings plus tailings will be recycled to primary spiral head feed.

An estimated 85% to 90% fine gold recovery is anticipated when the plant becomes operational.

MOUNTAIN HOME REDI-MIX INC.

This plant has been previously described in the Society of Mining Engineers of AIME Transactions Volume 272 by T. J. Ferree and L. F. Mashburn.

The plant is situated on the Snake River at Grand View, approximately 75 road miles due south of Boise, Idaho.

The first installation of a Reichert Cone Concentrator in a placer gold recovery system was commissioned in April 1980, when a Reichert Cone (type 4 DSV) and other gold recovery equipment was installed as an "add-on" to an existing aggregate plant.

The small aggregate operation, using semi-portable crushing and screening equipment, has a throughput of about 125 cubic yards/hour of bank-run gravel. The gravel, mined with a front-end loader, is crushed and washed through shaking screens to produce several sized fractions. The smallest size, containing the gold values, is a nominal 3/8".

The gold recovery circuit consists of two static DSM-type screens to remove the plus 20 mesh fraction from the minus 3/8" circuit feed, two Krebs D10B hydrocyclones to densify the minus 20 mesh screen undersize, a Reichert Cone Concentrator, and a single-deck full-size Deister wet shaking table. A simple amalgamation system recovers the gold from the table concentrate.

The gold recovery in the circuit is calculated to be in excess of 85%, based upon the known values in the bank-run gravel and the quantity of bullion recovered.

The significant feature of the gold recovery achieved in this case is the size range and flatness of the Snake River gold. Samples of gold recovered indicate that the gravity system is recovering gold down to 400 mesh (37 microns) with diameter to thickness ratios of 20:1.

Recently a Reichert Mark-7 Spiral Concentrator has been tested in place of the Deister shaking table and gold recoveries have remained constant in the 85% to 90% range.

CHENA MINING PROJECT

This plant situated on the Chena River is approximately 125 air miles due east of Fairbanks, Alaska.

Overall mine production is approximately 100 yards/hour of bank-run material. A Cat 245 Backhoe feeds into a trommel with the minus 1 1/2" undersize material feeding two 3 foot wide boxes, where a combination of angle iron and expanded metal riffles recover the coarse gold.

Six feet from the end of the box, an 8 mesh stainless steel screen is placed with a sump underneath. The last 4 feet of the box are blank to help discharge the plus 8 mesh oversize material plus approximately half the water flow.

The sump catches the other half of the water flow (1200 gpm at 3% solids by volume). The slurry is transferred from the sump to 2 hydrocyclones by a 6" X 8" trash pump. The underflow from the hydrocyclones feeds into a 2" Sala Vertical slurry pump (hydrocyclone underflow is approximately 80 gpm at 50% solids by weight).

The slurry is fed into a pressurized distributor feeding 2 triple-start Reichert Mark-7 Spiral Concentrators. Spiral middlings are recirculated back to the spiral feed pump and the spiral tailings are rejected. The spiral concentrate is taken daily to a clean-up shack for processing.

The complete fine gold recovery plant including the generator is mounted on skids for ease of mobility.

ACKNOWLEDGEMENTS

The writers wish to express their thanks and appreciation to the companies nominated in the paper for permission to describe their plants.

REFERENCES

(1) Fine Gold Recovery with a Reichert Cone - A Case History. T.J. Ferree and L.F. Mashburn.Society of Mining Engineers of AIME - Transactions Vol. 272

(2) The Mark-7 Spiral Concentrator - Fine Gold Recovery using Reichert Technology.
C.N. Robinson and T.J. Ferree. Fifth Annual Conference on Alaskan Placer Mining - March 1983.

FOOTNOTE

C.N. Robinson: Metallurgical Manager-North American
Mineral Deposits Limited

K. Dolphin: President of The Miner's Company - Fairbanks, Alaska

Mineral Deposits Limited - Agents in North America

Main Office: Denver, Colorado (303) 987-9310
Contact: Cliff Robinson/Tom Ferree

Consultant: Jacksonville, Florida (904) 272-7588
Contact: Brian Stratford

Canadian Agent: SALA Machine Works Ltd.
Mississauga (Toronto) Ontario
Contact: Bjorn Hagelstam (416) 270-2170

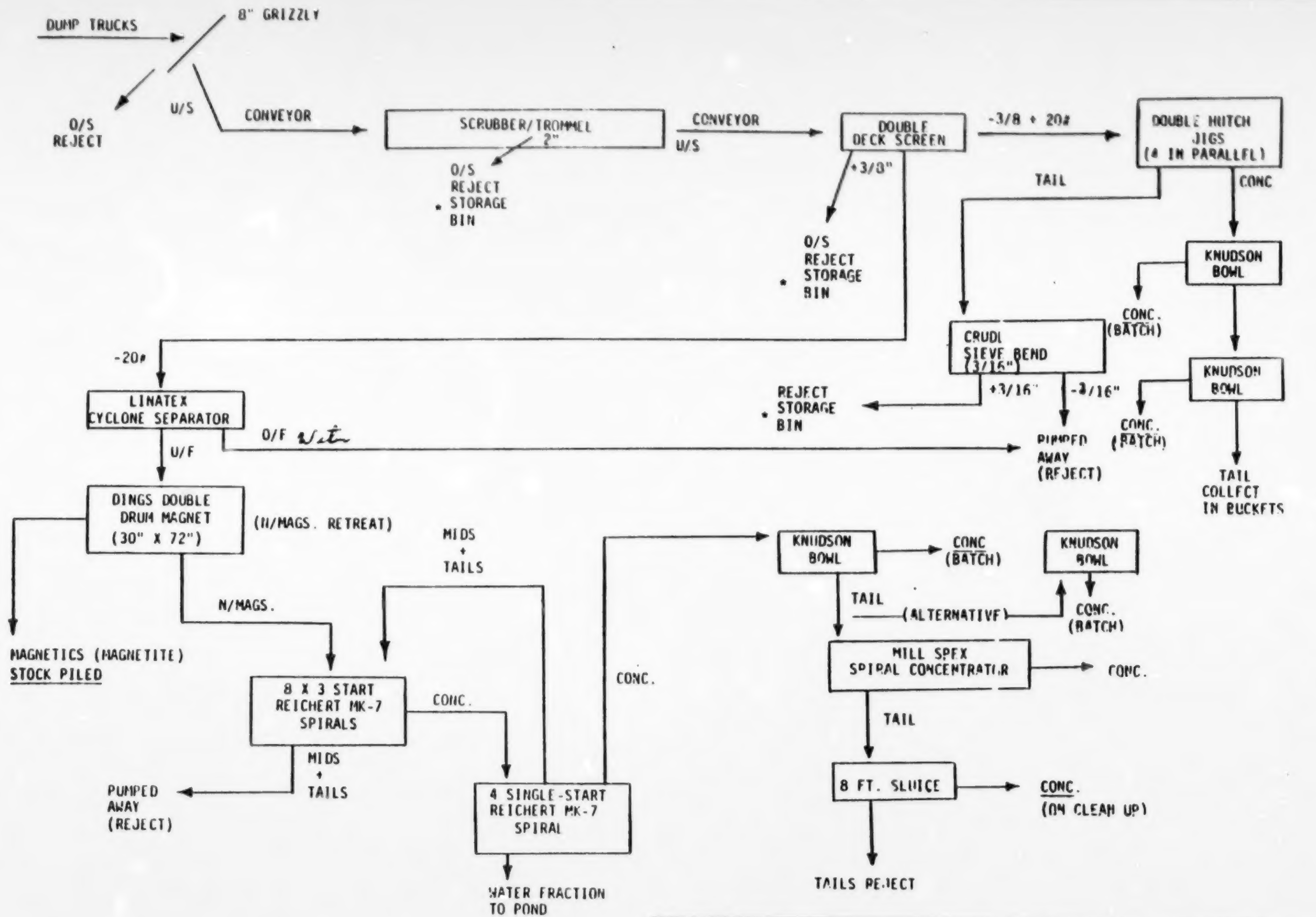
N.B. Through SALA's ownership by Allis-Chalmers, MDL is represented by A-C in Toronto, Ontario; Vancouver, B.C.: Montreal, Quebec; Edmonton, Alberta; Moncton, New Brunswick; Sudbury, Ontario.

Alaskan Agent: The Miner's Company, Fairbanks, Alaska (907) 452-8715
Contact: Kelly Dolphin

Mexican Agent: Fox Mexicana
Mexico City 584-99-88
Contact: Edgardo Gonzalez

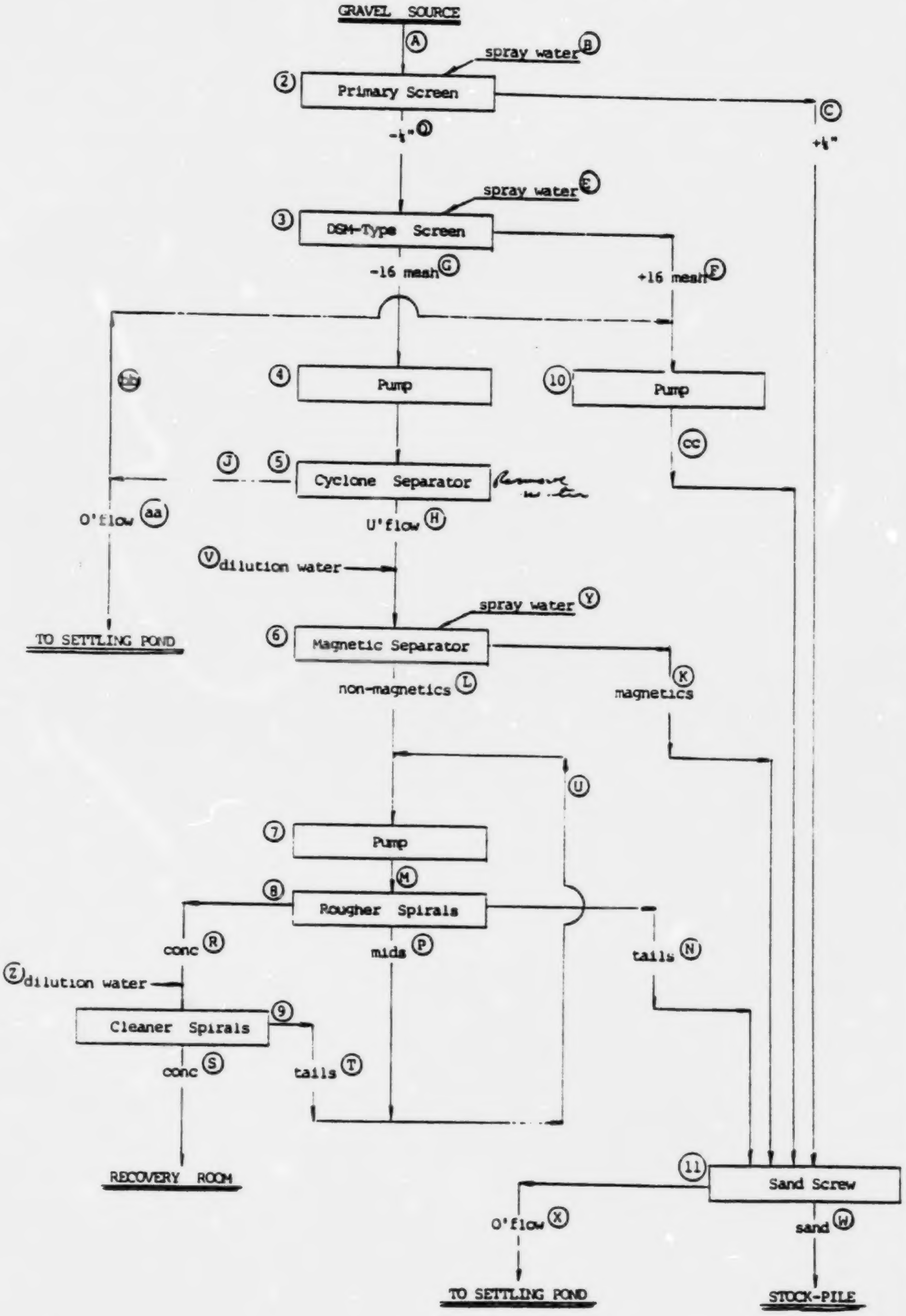
North Western USA Agent: Boise Assayers & Metallurgy, Inc.
Boise, Idaho (208) 345-6336
Contact: Larry Mashburn

** Test facilities are available throughout North America and test programs can be arranged through the above listed offices.


DUMP TRUCKS
8" GRIZZLY
O/S REJECT
U/S
CONVEYOR
SCRUBBER/TROMMEL
2"
O/S REJECT * STORAGE BIN
CONVEYOR
U/S
DOUBLE DECK SCREEN
+3/8"
O/S REJECT * STORAGE BIN
-3/8 + 20#
DOUBLE HUTCH JIGS (4 IN PARALLEL)
TAIL
CONC
KNUDSON BOWL
CONC. (BATCH)
CRUDL SIEVE BEND (3/16")
+3/16"
-3/16"
REJECT * STORAGE BIN
PUMPED AWAY (REJECT)
KNUDSON BOWL
CONC. (BATCH)
TAIL COLLECT IN BUCKETS
-20#
LINATEX CYCLONE SEPARATOR
O/F wtr
U/F
DINGS DOUBLE DRUM MAGNET (30" X 72")
(N/MAGS. RETREAT)
MAGNETICS (MAGNETITE) STOCK PILED
N/MAGS.
MIDS + TAILS
8 X 3 START REICHERT MK-7 SPIRALS
CONC.
MIDS + TAILS
PUMPED AWAY (REJECT)
4 SINGLE-START REICHERT MK-7 SPIRAL
WATER FRACTION TO POND
CONC.
KNUDSON BOWL
CONC (BATCH)
TAIL
(ALTERNATIVE)
KNUDSON BOWL
CONC. (BATCH)
MILL SPEX SPIRAL CONCENTRATOR
CONC.
TAIL
8 FT. SLUICE
CONC. (ON CLEAN UP)
TAILS REJECT

* PERIODICALLY CLEARED BY DUMP TRUCK

LYNX CORPORATION - PRESCOTT VALLEY PLANT (200-340 TPH — ALLUVIAL GOLD PLACER)	DRAWN: DATE: SCALE

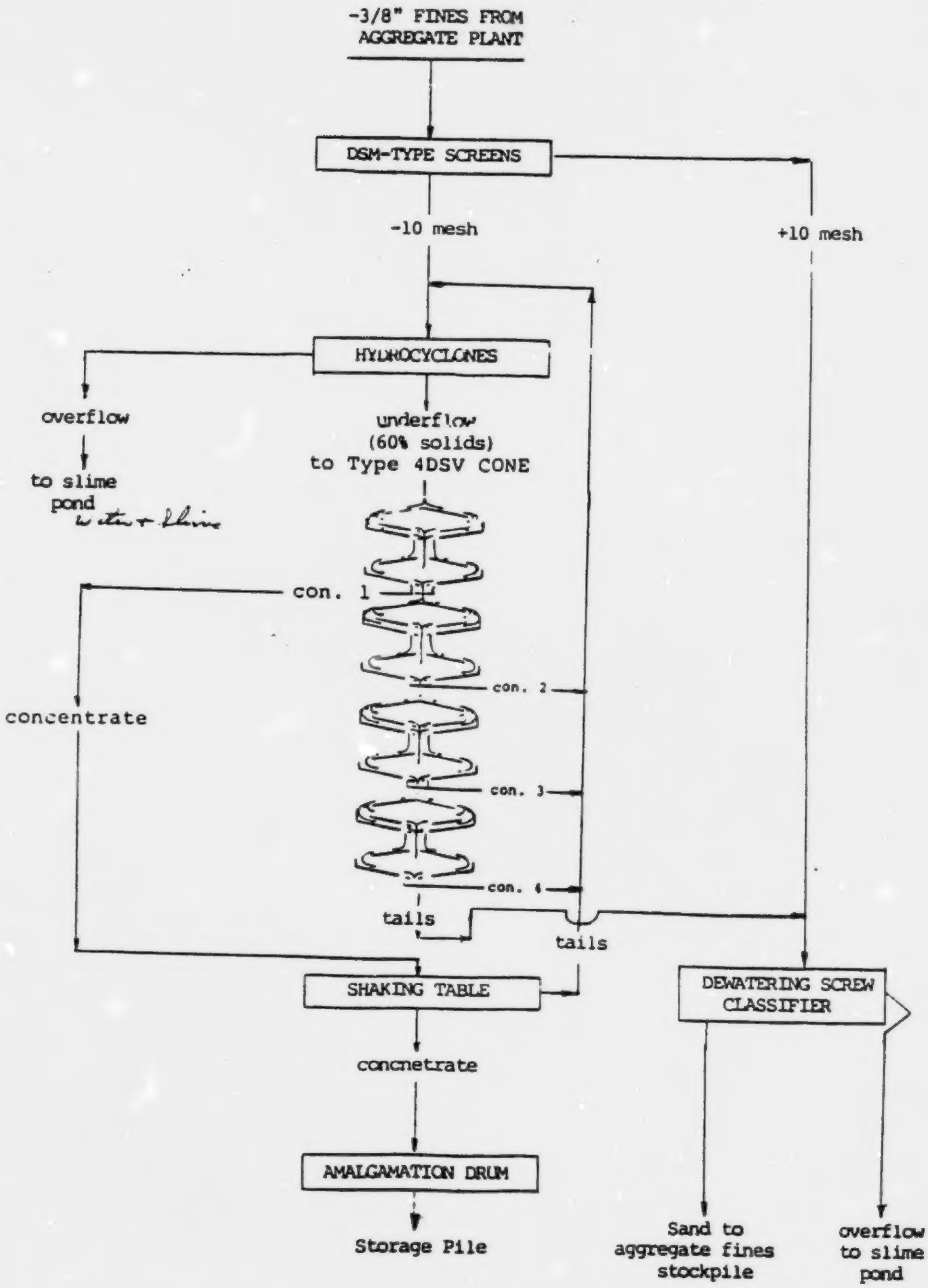

GRAVEL SOURCE
Ⓐ
spray water Ⓑ
② Primary Screen
Ⓒ +¼"
-¼" Ⓓ
spray water Ⓔ
③ DSM-Type Screen
-16 mesh Ⓖ
+16 mesh Ⓕ
bb
④ Pump
⑩ Pump
cc
Ⓙ
⑤ Cyclone Separator
Remove water
O'flow aa
U'flow Ⓗ
Ⓥ dilution water
TO SETTLING POND
spray water Ⓨ
⑥ Magnetic Separator
non-magnetics Ⓛ
Ⓚ magnetics
Ⓤ
⑦ Pump
Ⓜ
⑧ Rougher Spirals
conc Ⓡ
mids Ⓟ
tails Ⓝ
Ⓩ dilution water
Cleaner Spirals ⑨
conc Ⓢ
tails Ⓣ
RECOVERY ROOM
⑪ Sand Screw
O'flow Ⓧ
sand Ⓦ
TO SETTLING POND
STOCK-PILE

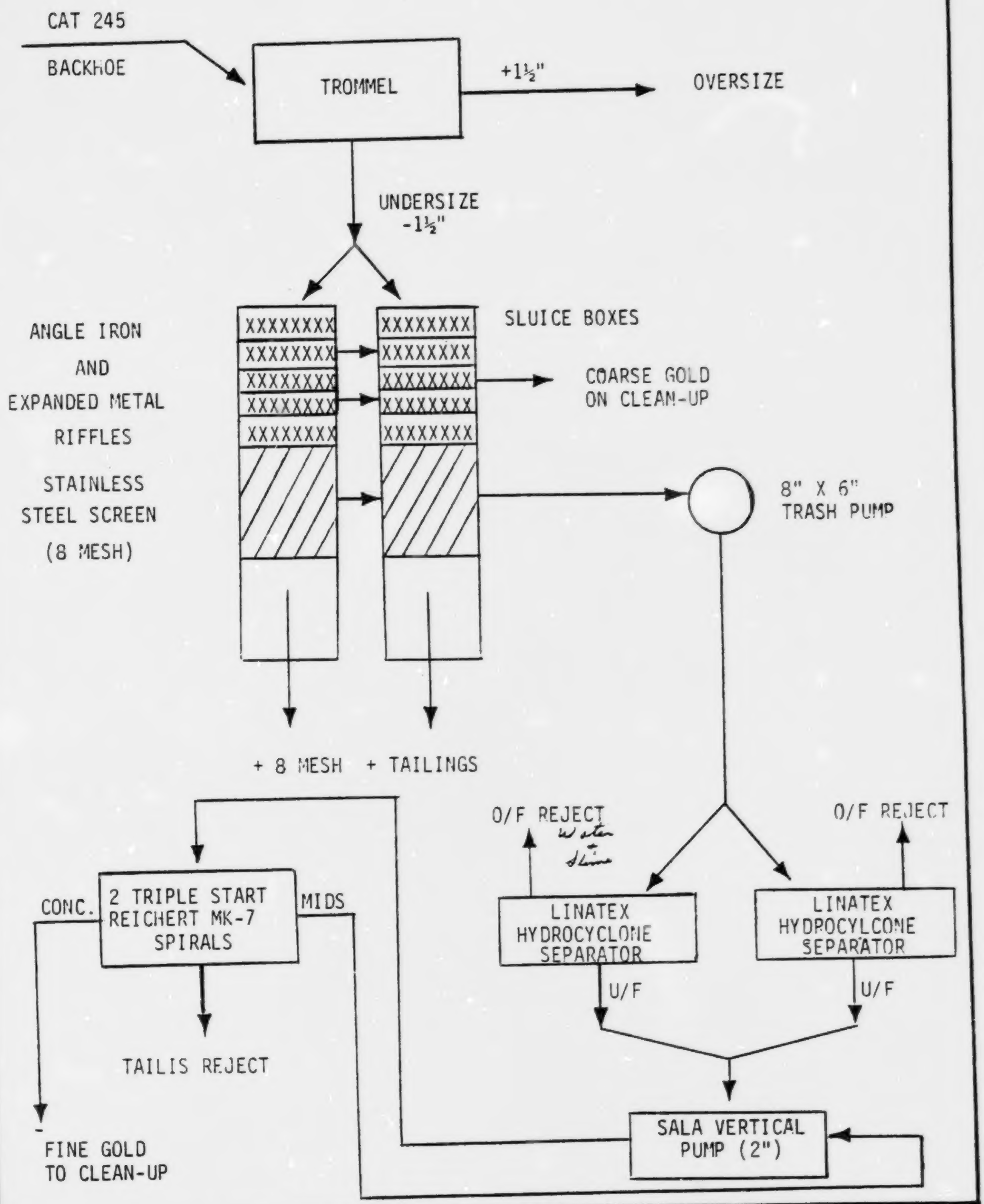
HANSEN BROTHERS PROJECT
Grass Valley, California

200 TPH

DRAWN TJF
DATE 2·20·83
SCALE None

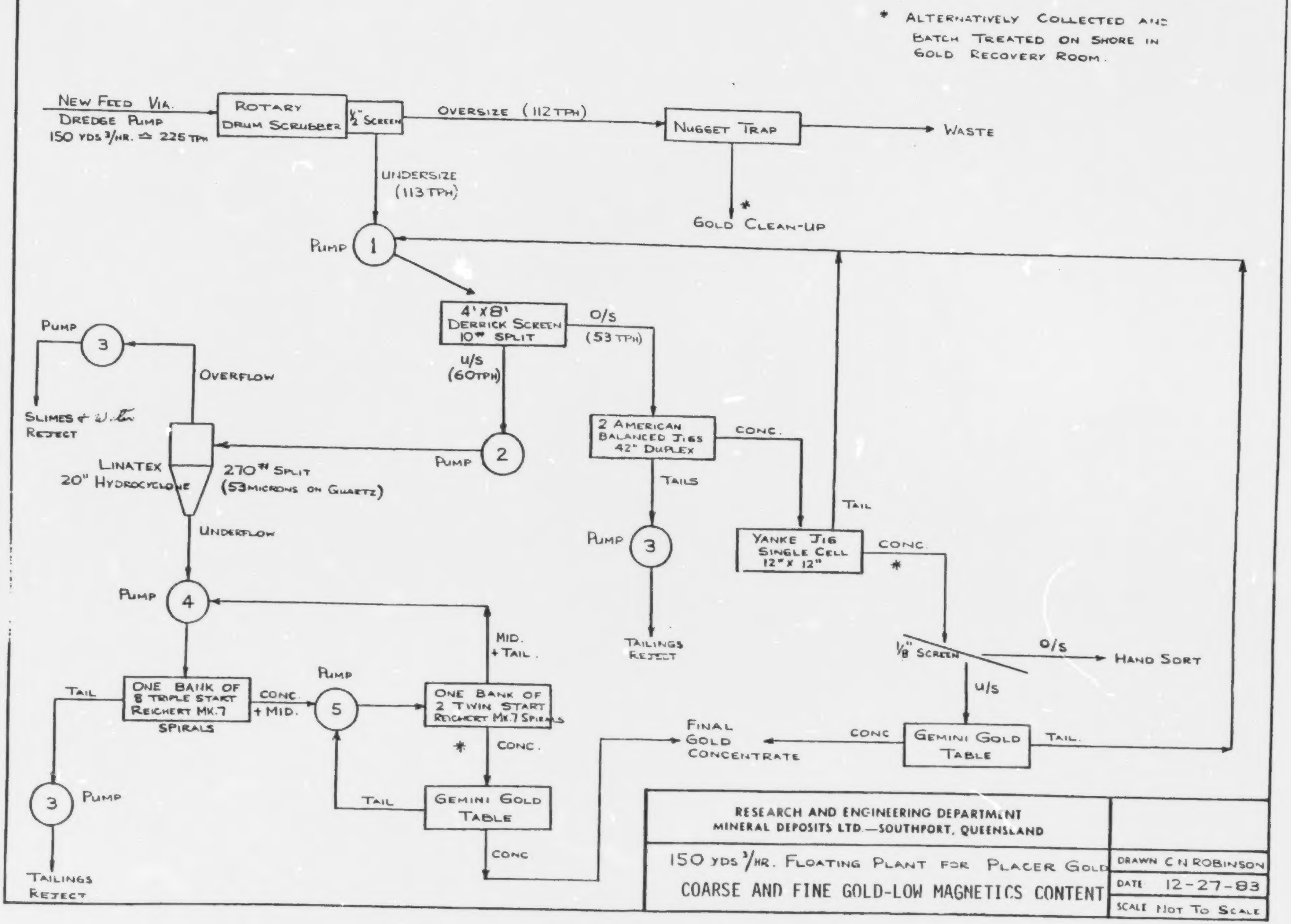
FINE GOLD RECOVERY SYSTEM IN THE SNAKE RIVER AGGREGATE PLANT


-3/8" FINES FROM AGGREGATE PLANT
DSM-TYPE SCREENS
-10 mesh
+10 mesh
HYDROCYCLONES
overflow
to slime pond
water + slime
underflow (60% solids) to Type 4DSV CONE
con. 1
con. 2
con. 3
con. 4
concentrate
tails
tails
SHAKING TABLE
concnetrate
AMALGAMATION DRUM
Storage Pile
DEWATERING SCREW CLASSIFIER
Sand to aggregate fines stockpile
overflow to slime pond


CAT 245
BACKHOE
TROMMEL
+1½"
OVERSIZE
UNDERSIZE
-1½"
SLUICE BOXES
ANGLE IRON
AND
EXPANDED METAL
RIFFLES
STAINLESS
STEEL SCREEN
(8 MESH)
XXXXXXXX
COARSE GOLD
ON CLEAN-UP
8" X 6"
TRASH PUMP
+ 8 MESH
+ TAILINGS
O/F REJECT
Water + Slime
O/F REJECT
LINATEX
HYDROCYCLONE
SEPARATOR
LINATEX
HYDROCYCLONE
SEPARATOR
U/F
U/F
CONC.
2 TRIPLE START
REICHERT MK-7
SPIRALS
MIDS
TAILIS REJECT
FINE GOLD
TO CLEAN-UP
SALA VERTICAL
PUMP (2")

CHENA MINING PROJECT
ALASKA (100 YDS^3/HR.)

DRAWN:
DATE:
SCALE:


New Feed Via.
Dredge Pump
150 yds ³/hr. ≏ 225 TPH
Rotary Drum Scrubber
½" Screen
Oversize (112 TPH)
Nugget Trap
Waste
Gold Clean-Up *
Undersize (113 TPH)
Pump 1
4'x8' Derrick Screen 10# Split
O/S (53 TPH)
U/S (60 TPH)
2 American Balanced Jigs 42" Duplex
Conc.
Tails
Pump 3
Tailings Reject
Yanke Jig Single Cell 12" x 12"
Tail
Conc. *
⅛" Screen
O/S
Hand Sort
U/S
Gemini Gold Table
Conc
Tail.
Final Gold Concentrate
Pump 2
Linatex 20" Hydrocyclone
270# Split (53 microns on Quartz)
Overflow
Pump 3
Slimes & Water Reject
Underflow
Pump 4
One Bank of 8 Triple Start Reichert Mk.7 Spirals
Tail
Conc. + Mid.
Pump 5
One Bank of 2 Twin Start Reichert Mk.7 Spirals
Mid. + Tail.
Conc. *
Gemini Gold Table
Tail
Conc
Pump 3
Tailings Reject

* Alternatively collected and batch treated on shore in Gold Recovery Room.

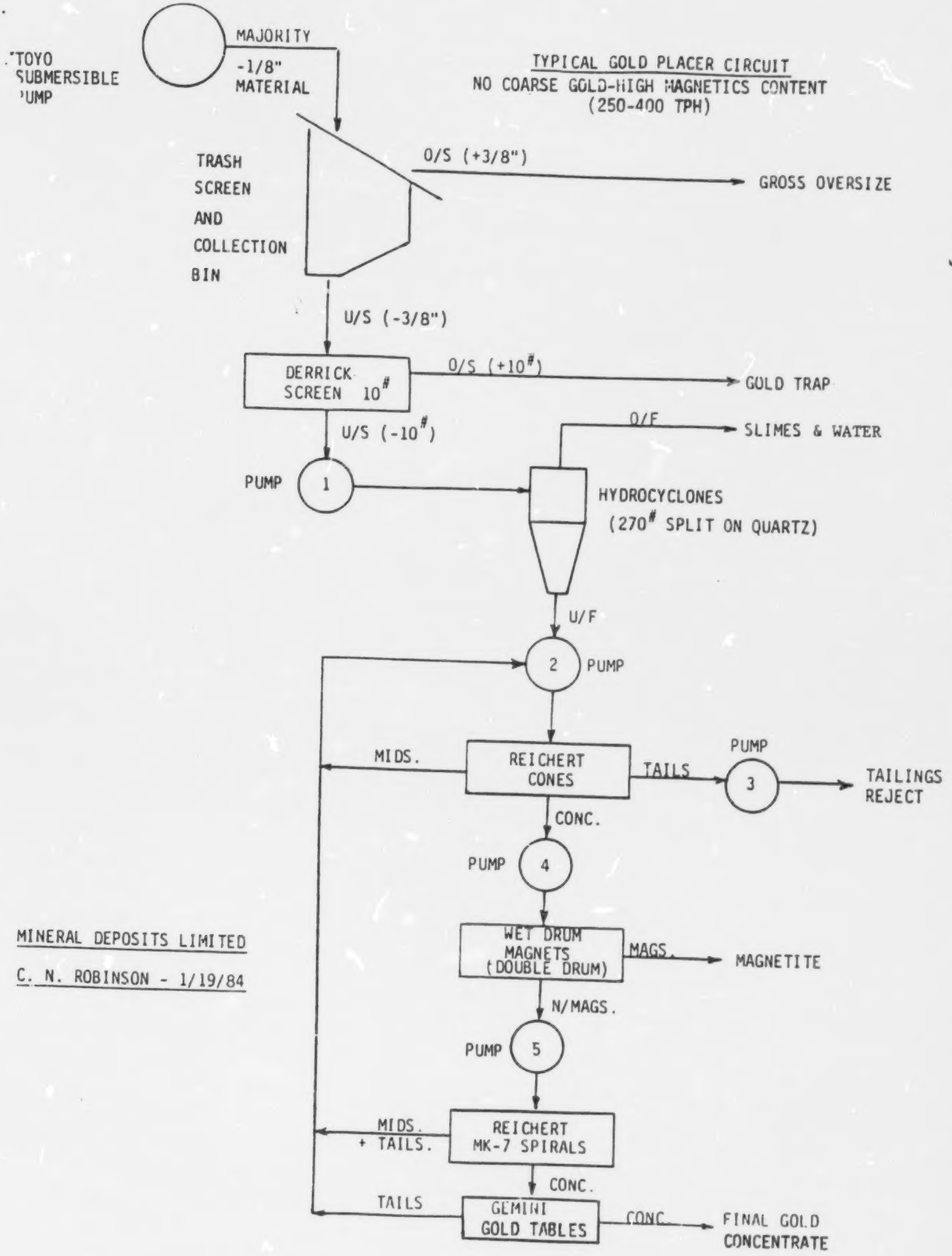
RESEARCH AND ENGINEERING DEPARTMENT
MINERAL DEPOSITS LTD.—SOUTHPORT, QUEENSLAND

150 YDS ³/HR. FLOATING PLANT FOR PLACER GOLD
COARSE AND FINE GOLD-LOW MAGNETICS CONTENT

DRAWN C N ROBINSON
DATE 12-27-83
SCALE NOT TO SCALE

TYPICAL GOLD PLACER CIRCUIT

NO COARSE GOLD-HIGH MAGNETICS CONTENT
(250-400 TPH)


TOYO SUBMERSIBLE PUMP
MAJORITY
-1/8" MATERIAL
TRASH SCREEN AND COLLECTION BIN
O/S (+3/8")
GROSS OVERSIZE
U/S (-3/8")
DERRICK SCREEN 10#
O/S (+10#)
GOLD TRAP
U/S (-10#)
O/F
SLIMES & WATER
PUMP
1
HYDROCYCLONES
(270# SPLIT ON QUARTZ)
U/F
2
PUMP
MIDS.
REICHERT CONES
TAILS
PUMP
3
TAILINGS REJECT
CONC.
PUMP
4
WET DRUM MAGNETS (DOUBLE DRUM)
MAGS.
MAGNETITE
N/MAGS.
PUMP
5
MIDS. + TAILS.
REICHERT MK-7 SPIRALS
CONC.
TAILS
GEMINI GOLD TABLES
CONC.
FINAL GOLD CONCENTRATE

MINERAL DEPOSITS LIMITED

C. N. ROBINSON - 1/19/84

APPENDIX D

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Volume

2

EVALUATION OF EQUIPMENT AND PROCESSES TO SAMPLE OFFSHORE PLACER DEPOSITS FROM SMALL FISHING VESSELS

VOLUME II

SURVEY OF EXISTING SAMPLING SYSTEMS

FINAL REPORT
BY:
NORDCO Limited

Work on the project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada, with funding provided under the Canada/Nova Scotia Mineral Development Agreement

NORDCO File Ref.: 303-85G
DSS File No.: 14SQ.23440-5-9230
DSS Contract Serial No.: 0SQ85-00287
CANMET Scientific Authority: Mr. D. Doyle
Mineral Processing
Laboratory

174 pp

Date: December 1986

MICROMEDIA

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EXECUTIVE SUMMARY

This volume forms part of a two-volume report, submitted to Canada Centre for Mineral and Energy Technology (CANMET), which gives the results of a study related to sampling and processing of offshore placer deposits, with particular reference to gold-bearing placers.

Full details of the study, including the Terms of Reference together with conclusions and recommendations, are given in Volume I.

This volume (Volume II) gives details of existing sampling systems which were evaluated as part of the study.

1.0 INTRODUCTION

This volume forms part of a two-volume report, submitted to Canada Centre for Mineral and Energy Technology (CANMET), which gives the results of a study related to sampling and processing of offshore placer deposits, with particular reference to gold-bearing placers.

2.0 TERMS OF REFERENCE

The detailed Terms of Reference (TOR) for the study are given in Volume I. For convenience, however, the following extract from the TOR relating to the evaluation of existing sampling systems, is included here:

> "The contractor will produce a comprehensive report assessing the capability and suitability of available drilling technologies that might be used for placer exploration in the Canadian Offshore. The report should also include costs and terms of purchase/lease of the various systems examined as well as suppliers. Recommendations will be made on possible improvements and the potential for modifying existing equipment for use on coastal fishing vessels so as to decrease the cost of exploration and create employment opportunities for Canadian fishermen."

3.0 STUDY DETAILS, CONCLUSIONS AND RECOMMENDATIONS

Full details of the study, together with conclusions and recommendations are given in Volume I.

This volume (Volume II) gives details of existing sampling systems which were evaluated as part of the study.

4.0 MARINE SAMPLING SYSTEMS

4.1 GENERAL

Existing methods of obtaining seafloor soil and rock samples generally fall into one of the following categories in terms of degree of sophistication, availability, mobilization and operational costs, and capability of producing the required data under a wide range of geotechnical and environmental conditions.

On the one hand, are various types of grab samplers (Sly, 1979) which are relatively simple to operate, readily available, and inexpensive and which do not require a specially modified or dedicated vessel as an operating platform. These systems are not suitable for sampling bedrock and in soils they can usually penetrate to only a very limited depth beneath the seabed, although they are capable of handling cobble sized stones and larger.

Placer deposits may be in excess of 30 m thick and may contain gold in significant concentrations in one or more thin stratified layers not necessarily at the surface. The amount of data which can be derived from samples obtained by grab sampling methods is limited and may bear no resemblance to the characteristics of the overall deposit.

Therefore grab samplers, in general, have not been considered for this study, although it should be noted that a proliferation of types and sizes exist, virtually all of which could be operated from a small fishing vessel if required.

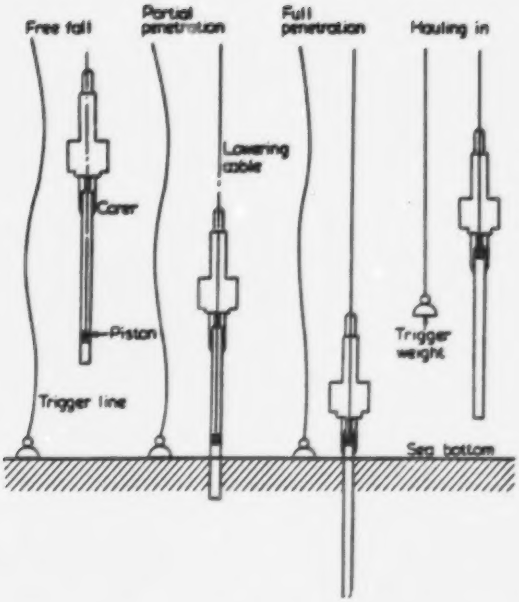
At the other extreme is the second category of existing equipment which includes purpose built geotechnical drillships (e.g. M.V. PHOLAS, M.S. FERDER, M.S. BUCENTAUR, etc.) or ships equipped with a moonpool to facilitate their use as a working platform on which conventional "on land" drillrigs, usually with some form of motion compensation, are mounted. This category of relatively sophisticated geotechnical drilling and sampling equipment also includes purpose built systems such as the Delft Mission II diving bell and drilling/testing system and various proprietary systems which are not generally available for use except by the (usually foreign) organizations which have developed them. The various types of equipment in this second category can provide reasonably complete information in a wide variety of conditions; however, the systems are of limited availability, and mobilization and operating costs are high.

The third category comprises equipment which in terms of availability, cost and capability, has been developed to bridge the gap between the two categories described above. This category includes gravity corers and seafloor mounted equipment including various forms of vibratory corers, rotary drills and jet airlift systems.

The details of typical equipment from this third group are summarized in the following sections.

4.2 GRAVITY CORERS

Gravity and gravity-piston corers are generally used to recover samples from soft unconsolidated soil. Cores up to 30 metres in length have been obtained in soft cohesive materials, however most good quality cores come from less than 2 metres of penetration with only 200-250 mm of core being generally recovered in sand or gravelly sand. Gravity coring is one of the simplest and most inexpensive methods of coring since the corer is essentially a length of steel pipe with an adjustable weight at the top. Most gravity corers today have an internal piston, hence the name gravity-piston corers. The piston aids in sample recovery and corer penetration by reducing friction and pressure as the sample enters the core barrel. Operation of a typical gravity-piston corer is shown in Figure 4.1.


Free fall
Partial penetration
Full penetration
Hauling in
Lowering cable
Corer
Piston
Trigger line
Trigger weight
Sea bottom

Gravity Piston Corer

Figure 4.1

The corer is lowered over the side of the ship in the vertical position. The trigger line releases the corer at a predetermined distance above the seafloor to enable it to freefall. Upon striking the seafloor the corer penetrates the sediment until the kinetic energy is dissipated in overcoming friction and end resistance on the corer.

Several variations of gravity corers have been developed since their use in the early 1900's, but all have limited sample depth capability and are mainly used for soft surficial sediments (silt and unconsolidated clay).

Essential features of the gravity corers examined as part of this study are given in Table 4.1. Further details of each of these systems follow:

TABLE 4.1 GRAVITY PISTON CORERS

	SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
1.	Multi-purpose Soft Sediment Sampler	Soft, cohesive Sediment	4.6 m	0.31m/76mm		0.5m/	None	Manually pushed into sediments	Ship Board winch only	Has been successfully used in the tidal flats and marshes of San Francisco Bay.
2.	Sphincter Corer	Unconsolidated Sediment	4000 m	4m / 120mm 8m / 120mm 12m / 120mm	1000 kg. for 12m unit	15m/	None	Gravity powered. Has own small generator for electrical control of piston while on bottom.	Ship Board winch only	Uses a split piston to prevent suction of the core upon retrieval.
3.	Woods Hole Ocean Inst. Giant Piston Corer	Unconsolidated Sediment	5500 m	30m / 114mm	4000 kg.	33m / 1m	None	2 - 3 m. of freefall for penetration/	Yes - uses a 300-1 mechanical advantage levering system on the load line	Uses a split piston to prevent suction of the core upon retrieval. Has been successfully deployed on the greater antilles and the Gulf of Maine by the R/V Knorr. Later lost at sea.
4.	Stored Energy Seabed Corer	Mud, Sand, Gravel	100 m	1.2m / 50mm	Unknown	1.5m/0.25m	None	Energy stored in 16 elastic cords released on impact with the sea floor.	Ship Board winch only	Has been successfully used in sheltered waters in Tasmania from a 12 m cabin launch.
5.	Marine Bio-medical Institute Box Corer	Unconsolidated Sediments	6000 m	1.14m / 47mm sq	1225 kg.	1.7m/.47m	None	Gravity Drop	Ship Board winch only	Has been successfully used in the nodule rich Abyssol - Hill Province in the North-west Atlantic.

TABLE 4.1 CONTINUED

	SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
6.	Unattached Sediment Sampler	Unconsolidated Sediments	1000 m	1.34m/240mm	82 kg.	2.0m/0.35m	None	Gravity drop	Ship Board winch only	Once the core has struck bottom the ballast is released and core barrel pulled to surface by buoys. Rest of sampler is lost.
7.	Institute of Oceanographic Sciences Box Corer	Unconsolidated Sediments	6000 m	0.6mm/300mm sq.	600 kg.	1.0m/0.5m	None	Gravity drop	Ship Board winch only	Uses lifting cable to close bottom jaws. Used successfully in Eastern Mediterranean, Nares Abyssal Plain, Peru upwelling and S.E. Pacific.
8.	Triple Corer	Clay, silty clay, sitts and glacio-lacustrine muds.	400 m	2.0m/67mm	28 kg.	2.5m/?	None	Gravity drop - 5m freefall	Ship Board winch only	Can take three cores simultaneously. Uses benthos tubes to aid in core retrieval. Used successfully in Lake Ontario, Erie and Huron.
9.	I.O.S. Multi-purpose gravity corer	Unconsolidated Sediment	6000m	1.2m/15mm square 1.0m/10mm 3.0m/60mm 3.0m/100mm	300 kg.	Approx 3.5m/1.0m	Uses pinger to locate seafloor for correct drop height.	Gravity drop - 50 to 100m freefall	Ship Board winch only	Has been used successfully in the N.W. African upwelling, the Nares Abyssal Plain, the Peru upwelling and the S.E. Pacific in seastates of 4/5.
10.	Benthos Corer	Sediments	6000 m	3m/66mm	900 kg.	Approx. 3.5m/?	None	Gravity drop	Ship Board winch only	Uses piston to aid core retrieval. Has pressure activated safety arming pin to prevent corer release before it is underwater.

TABLE 4.1 CONTINUED

SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
11. Long Coring Facility	Unconsolidated Sediments	6500 m	50m/110 mm	15,400 kg	55m /.25m	Records depth, tilt and rotation Uses acoustic system to trigger freefall and release parachute	Gravity drop	Ship Board winch only	Uses a ribbon parachute near bottom for support. Uses tapered core barrel 110mm at mouth and 222mm at upper end. Unit has never been constructed. Could only be used from large oceanographic vessel.
12. Long Hydroplastic sediment corer	Silty clays	900 m	8m/80mm	200 kg	9m/?	None	Gravity freefall 2.5m - 3.0 m	Ship Board Winch only	Based on the original design of Richards in 1961. Used successfully throughout the Mediterranean
13. Stacor	Soft Sediment	6000 m	30m/110mm	10,000 kg	31m/1m	None	Gravity freefall	Ship Board winch up to 60 tonnes	Uses fixed piston for core retrieval and taut line for corer release. Used in Gulf of Lions, France (82) from the "Nadir" in up to 1225m water depths. In 1985, used successfully in 6000 m water depth. 30 m long cores successfully raised (Fay et al 1985)

4.2.1 Multi-Purpose Soft Sediment Sampler (Figure 4.2)

Developed by Department of Geology, San Francisco State College, California, 1967 (Pestrong 1969).

This system is capable of recovering 76 mm diameter cores, up to 305 mm in length from soft cohesive sediment in water depths up to 4.6 m.

The core barrel, with the piston locked in place at its front edge, is forced (manually) down to the desired depth. This piston is then released, and held in place, while the core barrel is forced down past it. The piston is again locked in place, and the entire apparatus brought up to the surface.

This device was designed to be easily transported and utilized by just one operator.

The unit has successfully been used on the tidal flats and marshes of San Francisco Bay.

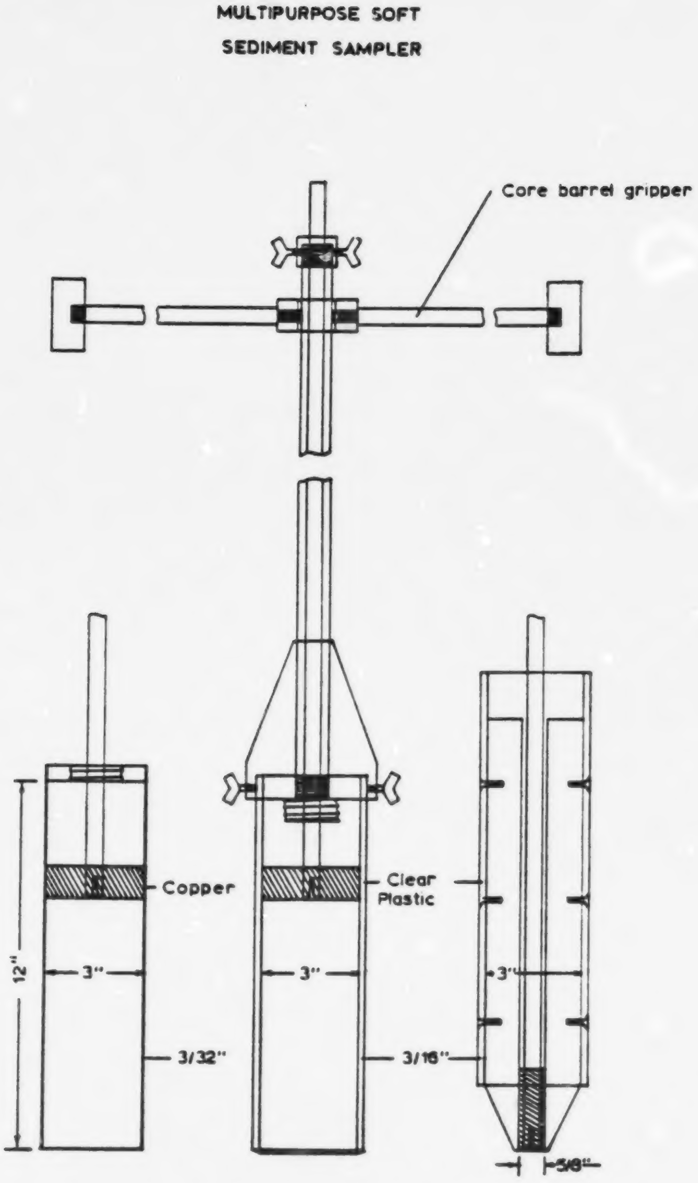

MULTIPURPOSE SOFT SEDIMENT SAMPLER
Core barrel gripper
Copper
Clear Plastic
12"
3"
3"
3"
3/32"
3/16"
5/8"

Figure 4.2 - Multipurpose Soft Sediment Sampler

4.2.2 Sphincter Corer (Figure 4.3)

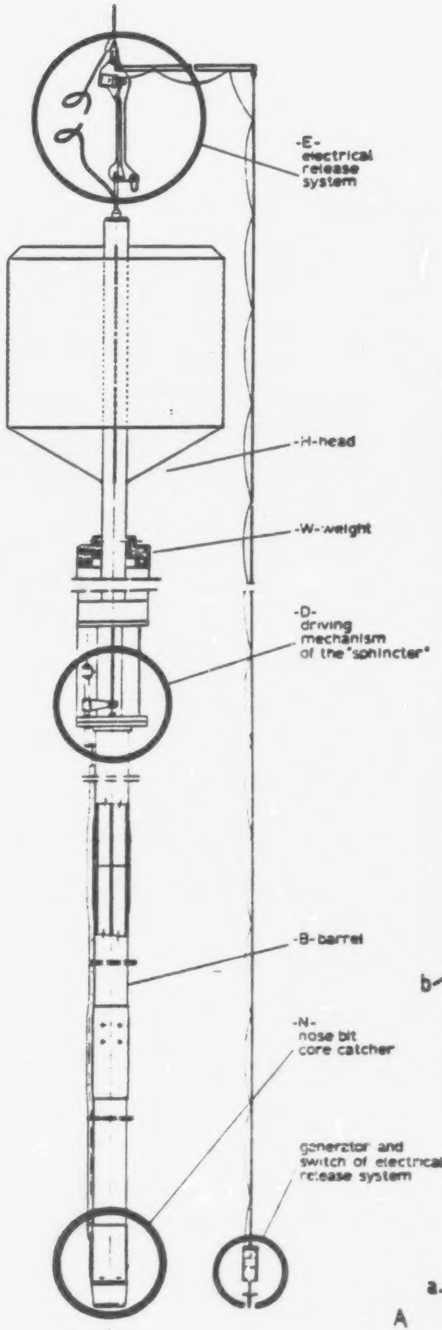
Developed by Saclant A.S.W. Research Centre, La Spezia, Italy, 1966. Modified with Recoilless Piston in 1968 (Kermabon et al. 1966, Kermabon and Cortis 1969).

This system is capable of recovering a 120 mm diameter core, in 4, 8, 12 and 15 m lengths. It has a maximum water depth capability of 4000 m and has successfully been used off the coast of Italy to that depth.

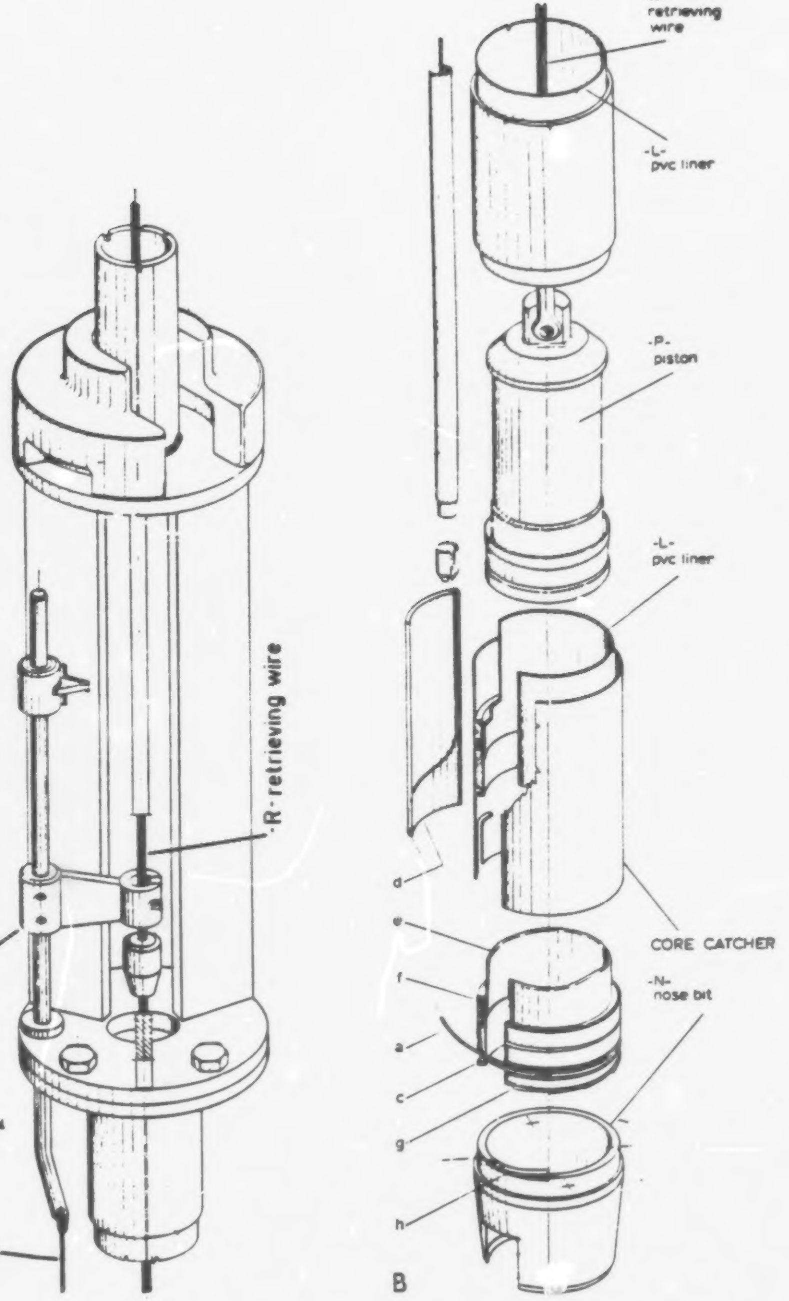
The 12 m unit is 15 m high and weighs 1000 kg. It relies on gravitation force to penetrate unconsolidated sediment. The corer uses a rotating "Sphincter Type" core-catcher, which seals the core within a watertight nylon sleeve during retrieval. The unit also utilizes a split piston to improve core retention when the corer is retrieved from the sediment. To prevent excessive suction on the core if the corer is not completely filled with sediment, an electrically triggered delay mechanism is used which frees the piston from the pulling line after a precalculated time. The system also uses an electrical corer release system which prevents accidental triggering due to sudden shocks.

In about 1968, the system was modified by the incorporation of a "recoilless piston" designed to maintain the piston stationary relative to the seafloor during sampling operations. This is achieved by the use of a light circular platform, around the corer tube, which rests on the seafloor and is connected to the sampler piston by means of a 6 mm diameter wire rope and a system of pulleys at the upper and lower ends of the corer and on the sampler piston. The wire rope is fixed at both ends to the platform, passes under the two lower corer pulleys, up over the two upper pulleys and then passes down inside the corer to the pulley on the sampler piston.

The platform is designed to have a sufficiently large bearing area to prevent it from penetrating into the sediments and this keeps the piston at seafloor level whilst the barrel penetrates normally by gravity.


-E-
electrical release system
-H-head
-W-weight
-D-
driving mechanism of the "sphincter"
-B-barrel
-N-
nose bit core catcher
generator and switch of electrical release system

The "Sphincter", 120 mm corer.


A
a
b
-R- retrieving wire
B
-R-
retrieving wire
-L-
pvc liner
-P-
piston
-L-
pvc liner
CORE CATCHER
-N-
nose bit
d
e
f
a
c
g
h

A. Driving mechanism of the "sphincter". B. Nose

Figure 4.3 - Sphincter Corer

(Recoilless piston arrangement not shown)

4.2.3 Giant Piston-Corer (Figure 4.4)

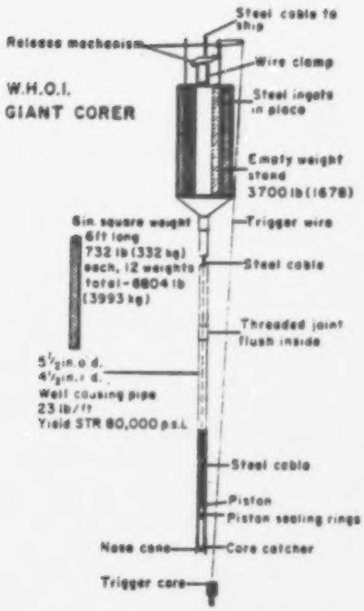
Developed by the Woods Hole Oceanographic Institution, Mass. and Worcester Polytechnic Institute, Worchester, Mass., 1969 (Hollister et al. 1973).

This system is capable of recovering 114 mm diameter cores, 30 m long from unconsolidated sediment in water depths up 5500 m.

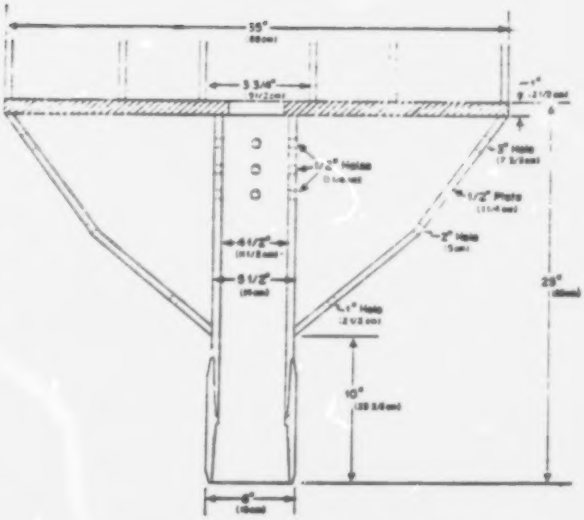
The unit weighs between 3200 and 4000 kg and relies on a 2 - 3 m freefall for penetration. A trigger release mechanism actuates free-fall of the corer and the system utilizes a split piston which helps to retain the core when the corer is retrieved from the sediment. The load line is torque balanced and the lever system in the core head provides a mechanical pullout advantage of 300 to 1.

This corer has successfully been deployed from the R/V KNORR on the greater Antilles' outer ridge north of the Puerto Rico Trench and the Stellwagen Basin in the Gulf of Maine.

The system was later lost at sea when it could not be retrieved from the seabed. It was to be superceded with the "Long Coring Facility Corer."


W.H.O.I.
GIANT CORER
Release mechanism
Steel cable to ship
Wire clamp
Steel ingots in place
Empty weight stand
3700 lb (1678)
6in. square weight
6ft long
732 lb (332 kg)
each, 12 weights
total - 8804 lb
(3993 kg)
Trigger wire
Steel cable
Threaded joint
flush inside
5½in. o d.
4½in. i d.
Well causing pipe
23 lb/ft
Yield STR 80,000 p.s.i.
Steel cable
Piston
Piston sealing rings
Nose cone
Core catcher
Trigger core

Schematic diagram of W.H.O.I. giant corer.


55"
3 3/4"
1"
1/2" Holes
3" Hole
1/2" Plate
2" Hole
4 1/2"
5 1/2"
1" Hole
29"
10"
6"

Piston stop/baseplate, inletted holes and pipe sections.

Figure 4.4 - Giant Piston Corer

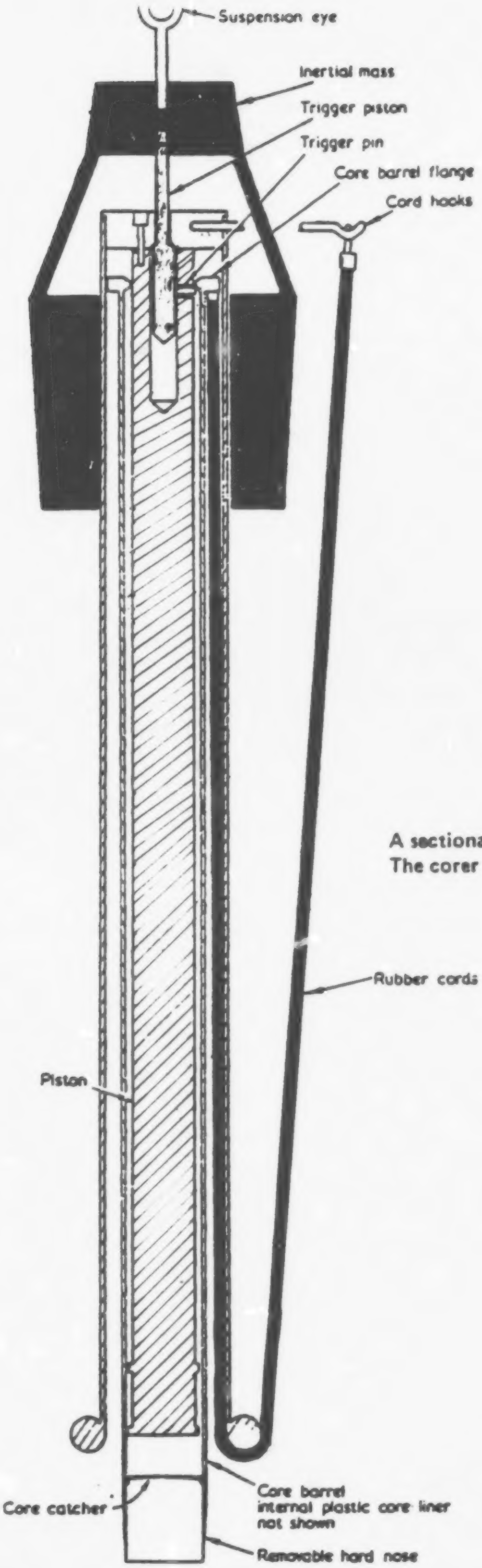
4.2.4 Stored Energy Seabed Corer (Figure 4.5)

Developed by School of Earth Sciences, Macquarie University, Sydney, Australia, 1973 (Roots 1973).

This system is capable of taking a 50 mm diameter core, 1.2 m long from sediment consisting of mud, sand, and gravel, in water depths up to 100 m.

Between four and sixteen rubber cords are stretched to provide the necessary stored elastic energy, the number depending upon the type of sediment being cored. Upon striking the seabed, the core barrel is retarded relative to the inertial mass which pushes the trigger piston down, and permits the trigger pin to move out of the way of the core barrel flange. The core barrel is then rammed into the seabed, in less than one second.

This system has been successfully used in Macquarie Harbour, Tasmania, where it was deployed from a 12 m cabin launch.


Suspension eye
Inertial mass
Trigger piston
Trigger pin
Core barrel flange
Cord hooks
Rubber cords
Piston
Core catcher
Core barrel
internal plastic core liner
not shown
Removable hard nose

A sectional view of the stored energy seabed corer. The corer is shown in the loaded position

Figure 4.5 - Stored Energy Seabed Corer

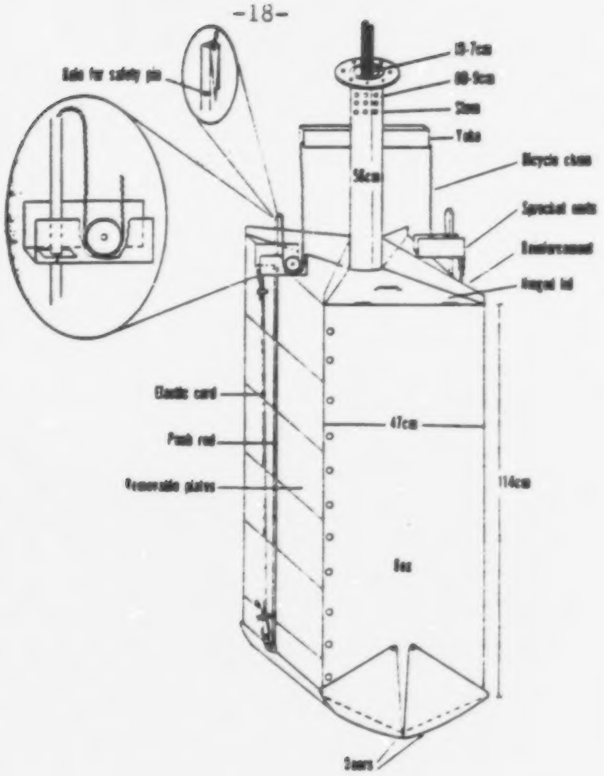
4.2.5 MBI Box Corer (Figure 4.6)

Developed by the Earth and Planetary Sciences Division, Marine Biomedical Institute, University of Texas Medical Branch, Texas, 1973 (Addy and Ewing 1979).

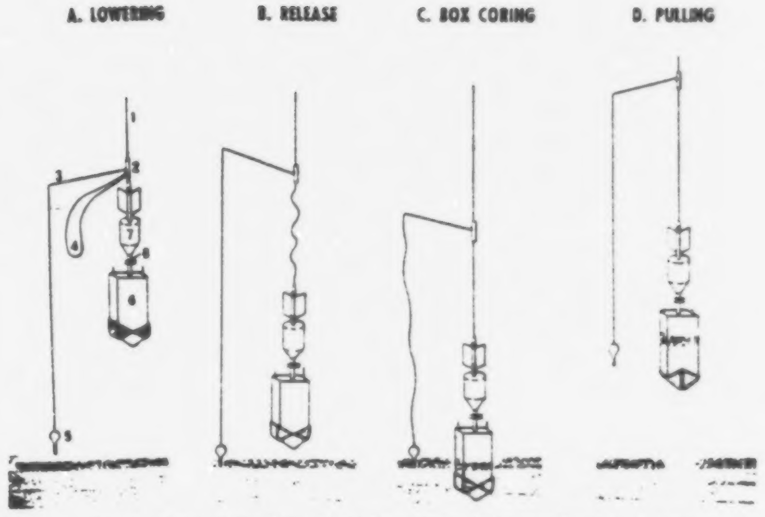
This system is capable of recovering 470 mm x 470 mm cores 1.14 m long from unconsolidated sediment in water depths up to 6000 m. The unit has a weight of 1225 kg.

The box corer uses the same piston core-head (1000 kg) and the same trigger mechanism as used in piston coring. The trawl wire (13 mm diameter) which passes through the center of the piston core-head is fastened to the yoke inside the stem. The two doors at the bottom of the box corer are closed by two push rods that are attached to the yoke by bicycle chains through the sprocket units on the box. While lowering, the two doors are held open by two elastic cords, one on each side, joining the door to the sprocket unit. When the doors are open the push rods are pushed upward, as a result the yoke slides down and is positioned at the base of the stem. The push rod can be held at this upward position by a safety pin which locks the push rod to the sprocket unit.

The MBI corer has successfully been used in the Nodule-Rich Abyssal-Hill province in the Northwest Atlantic.


Hole for safety pin
Yoke
Bicycle chain
Sprocket units
Reinforcement
Hinged lid
56cm
Elastic cord
Push rod
Removable plates
47cm
114cm
Box
Doors

Schematic diagram of the box corer in closed position.


A. LOWERING
B. RELEASE
C. BOX CORING
D. PULLING
1
2
3
4
5
6
7
8

The four stages of the operation of the box corer. The numbers in A represent: 1. trawl line; 2. release mechanism; 3. trigger arm; 4. scope; 5. trigger core and trigger weight; 6. box corer; 7. piston core-head with stabilizing fins, and 8. coupling.

Figure 4.6 - M.B.I. Box Corer

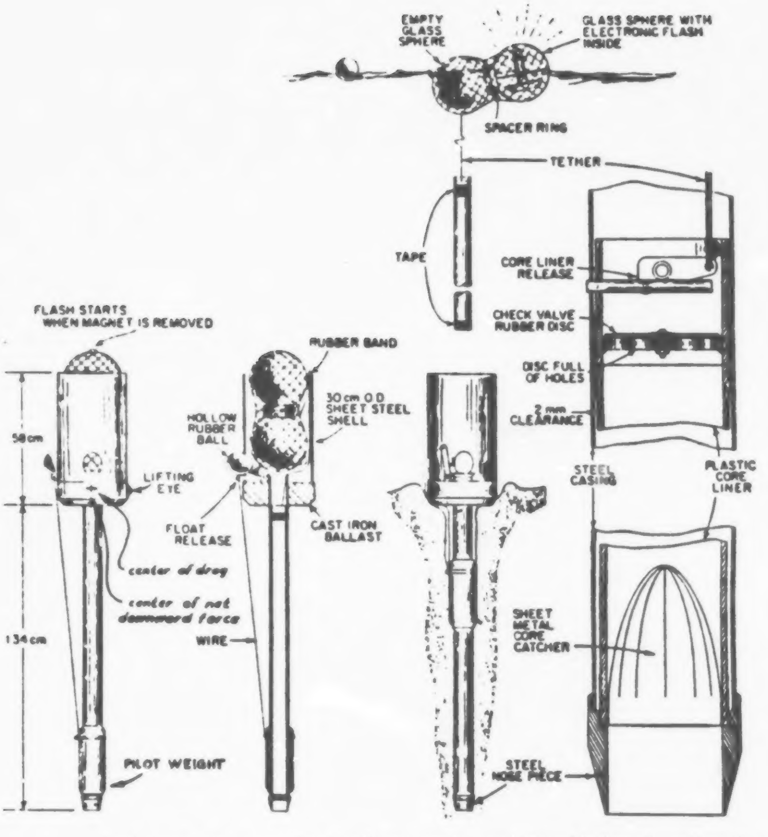
4.2.6 Unattached Sediment Sampler (Figure 4.7)

Developed by Woods Hole Oceanographic Institution and Benthos Co., Massachusetts, 1974 (Sachs and Raymond 1965).

This system is capable of taking a 240 mm diameter core, 1.34 m long from unconsolidated sediment in water depths up to 1000 m.

The unit is 2.0 m high and weighs 82 kg in air. It employs an expendable iron-ballast steel casing combination, and a recoverable glass-float, plastic-liner assembly.

The sampler is dropped over the side of the vessel and acts as a gravity/piston corer. Upon penetration of the sediment the ballast section is released and the core buoyed to the surface. The recoverable part of the assembly, on reaching the surface, is located by means of a built in flash.


EMPTY GLASS SPHERE
GLASS SPHERE WITH ELECTRONIC FLASH INSIDE
SPACER RING
TETHER
TAPE
CORE LINER RELEASE
CHECK VALVE RUBBER DISC
DISC FULL OF HOLES
2 mm CLEARANCE
STEEL CASING
PLASTIC CORE LINER
SHEET METAL CORE CATCHER
STEEL NOSE PIECE
FLASH STARTS WHEN MAGNET IS REMOVED
RUBBER BAND
30 cm O.D. SHEET STEEL SHELL
HOLLOW RUBBER BALL
58 cm
LIFTING EYE
FLOAT RELEASE
CAST IRON BALLAST
center of drag
center of net downward force
WIRE
134 cm
PILOT WEIGHT

Final design of the unattached sediment sampler consisting of hollow glass-sphere float and cast-iron ballast.

Figure 4.7 - Unattached Sediment Sampler

4.2.7 IOS Box Corer (Figures 4.8a and 4.8b)

Developed by the Institute of Oceanographic Sciences, Wormley, England and the Department of Oceanography, University of British Columbia, Vancouver, B.C., 1974 (Peters et al. 1980).

This system is capable of recovering 300 mm x 300 mm cores 0.6 m long from unconsolidated sediment in water depths up to 6000 m. The unit has a weight in air of 600 kg.

Closure at the top and bottom of the I.O.S. corer is achieved by pivoted shovel arms working in a scissor mode. As the load in the lifting straps increase when the corer is withdrawn from the sediment, the arms rotate and the shovels close off the top and bottom ends of the corer.

This unit has successfully been used in the Eastern Mediterranean, Nares Abyssal Plain, Peru Upwelling, and the S.E. Pacific.

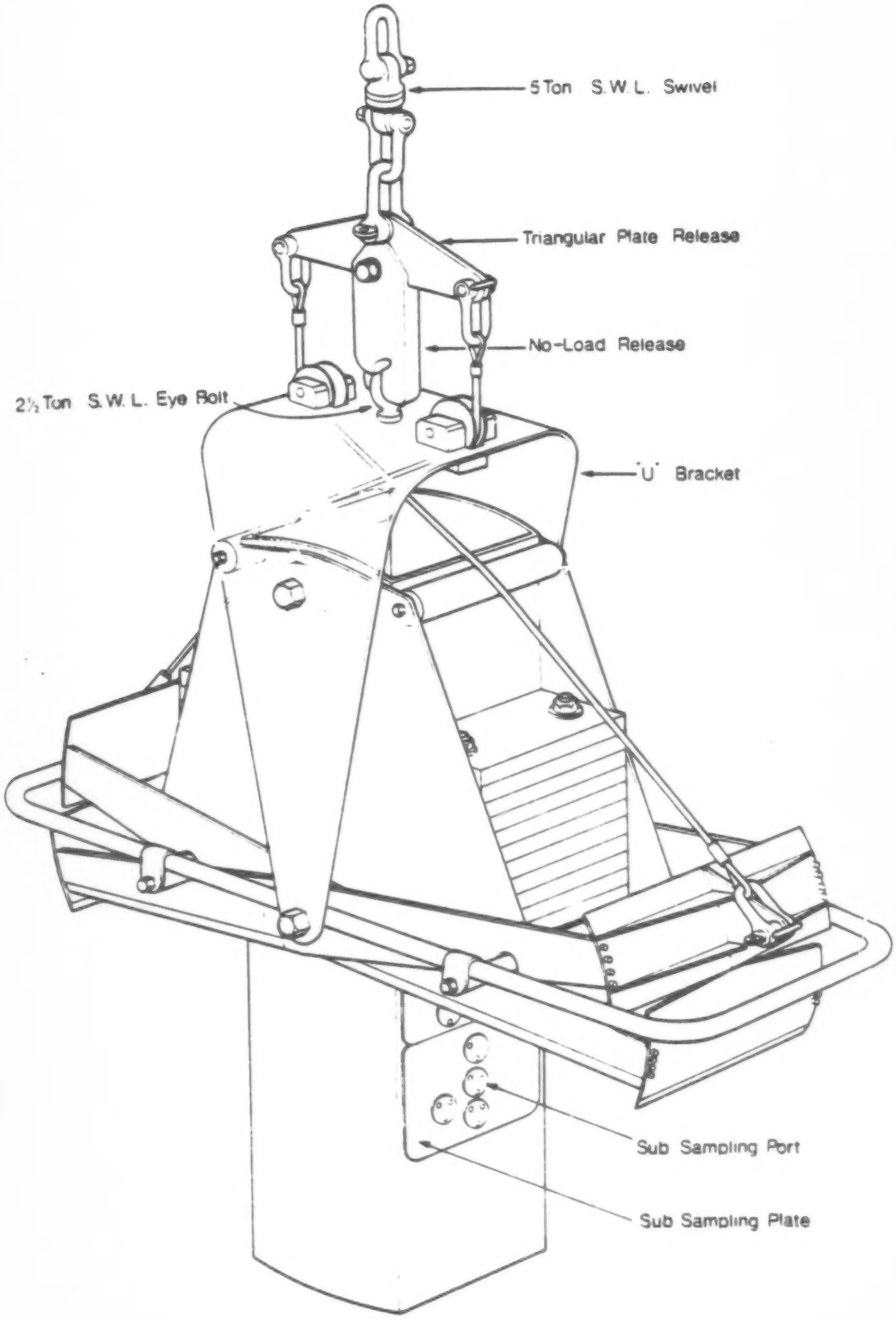
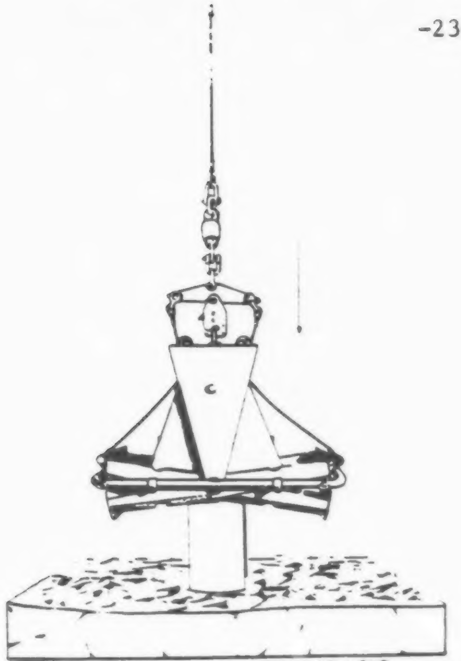
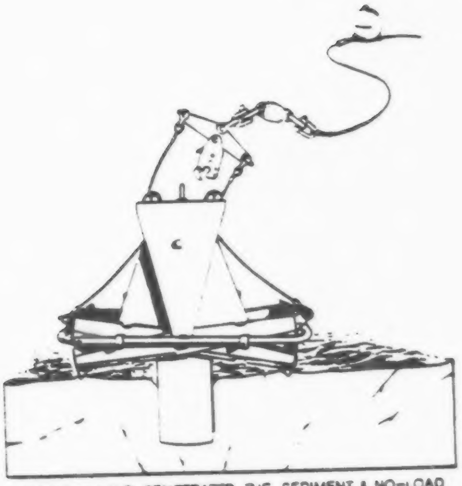

5 Ton S.W.L. Swivel
Triangular Plate Release
No-Load Release
2½ Ton S.W.L. Eye Bolt
'U' Bracket
Sub Sampling Port
Sub Sampling Plate

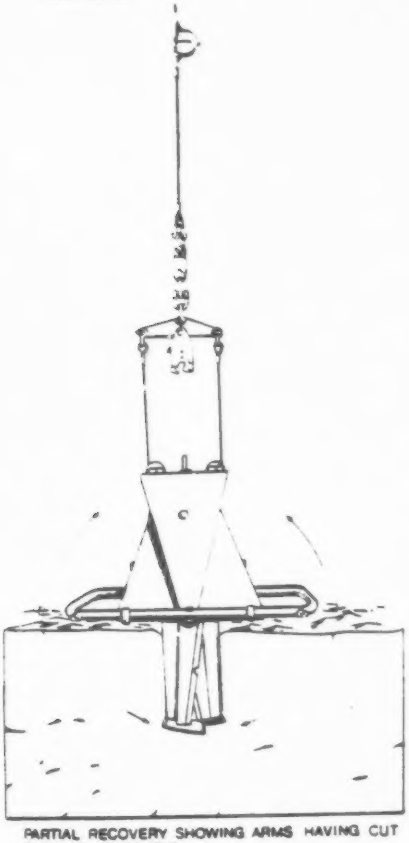
Figure 4.8(a) - I.O.S. Box Corer



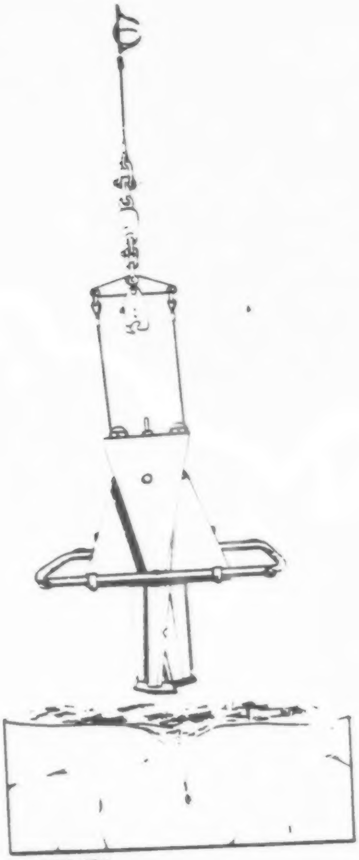
DESCENT MODE WITH ARMS OPEN & NO-LOAD RELEASE SET



CORER HAVING PENETRATED THE SEDIMENT & NO-LOAD RELEASE TRIPPED



PARTIAL RECOVERY SHOWING ARMS HAVING CUT THROUGH SEDIMENT



RECOVERY

Figure 4.8(b) - I.O.S. Box Corer Operation

4.2.8 Triple Corer (Figure 4.9)

Developed by Canada Centre for Inland Waters, Burlington, Ontario (Kemp et al. 1971).

This system is capable of recovering 3 simultaneous cores 66.8 mm in diameter, in lengths of 0.5, 0.75, 1.0 or 2.0 m. Cores can be taken from clay muds, silty clay muds, silts, and glacio-lacustrine clays at water depths up to 400 m. The unit equipped with steel coring tubes weighs 28 kg.

The 0.5 m unit is 0.9 m high. It relies on a 5 m freefall for sediment penetration and utilizes benthos valves in conjunction with a triggering system to prevent suction of the core when the corer is retrieved from the sediment.

The triple corer has successfully been used in Lake Ontario, Lake Erie and Lake Huron.

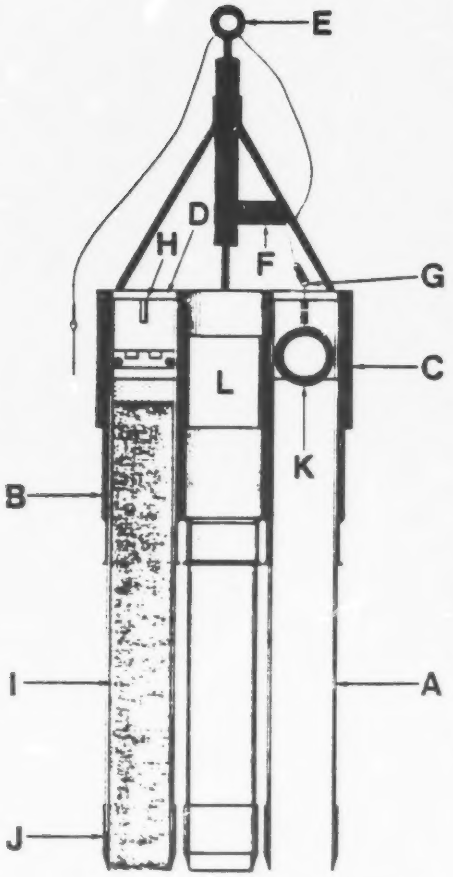
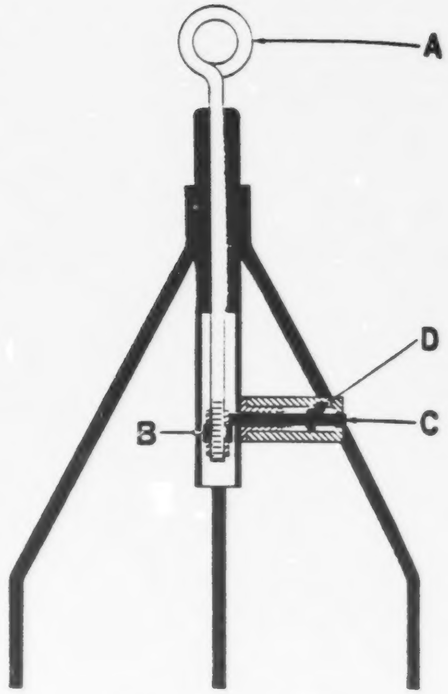


Diagram of section of triple corer. A—Core tube. B—Core barrel. C—Outer ring. D—Retaining stops. E—Lifting rod. F—Trigger mechanism. G—Valve pin. H—Benthos valve in closed position. I—Mud sample with overlaying water. J—Metal core cutter. K—Valve in open position. L—Inner core barrel.



Sectional diagram of trigger mechanism. A—Lifting rod. B—Collar. C—Trigger pin. D—Safety pin.

Figure 4.9 - Triple Corer

4.2.9 IOS Multi-Purpose Gravity Corer (Figure 4.10)

Developed by Institute of Oceanographic Sciences, Wormley, England, 1981 (Morris and Peters 1981).

This system is capable of recovering 150 mm x 150 mm cores 1.2 m long; 100 mm diameter cores 1.0 m long; and 60 and 100 mm diameter cores 3.0 m long. These cores can be taken from unconsolidated sediment in water depths up 6000 m.

The corer is deployed from, and recovered to, a tripod stand which is bolted onto the ship's deck. The stand keeps the corer in an upright position to minimize sample disturbance. The sampler weighs 300 kg. in air and relies on gravitation force from a 50 - 100 m freefall to penetrate sediment. This distance is indicated by a pinger located further up the load line.

The IOS corer has successfully been deployed in seastates of 4 to 5 (Beaufort Scale) and used in the N.W. African upwelling region, the Nares Abyssal Plain, the Peru upwelling and the S.E. Pacific.

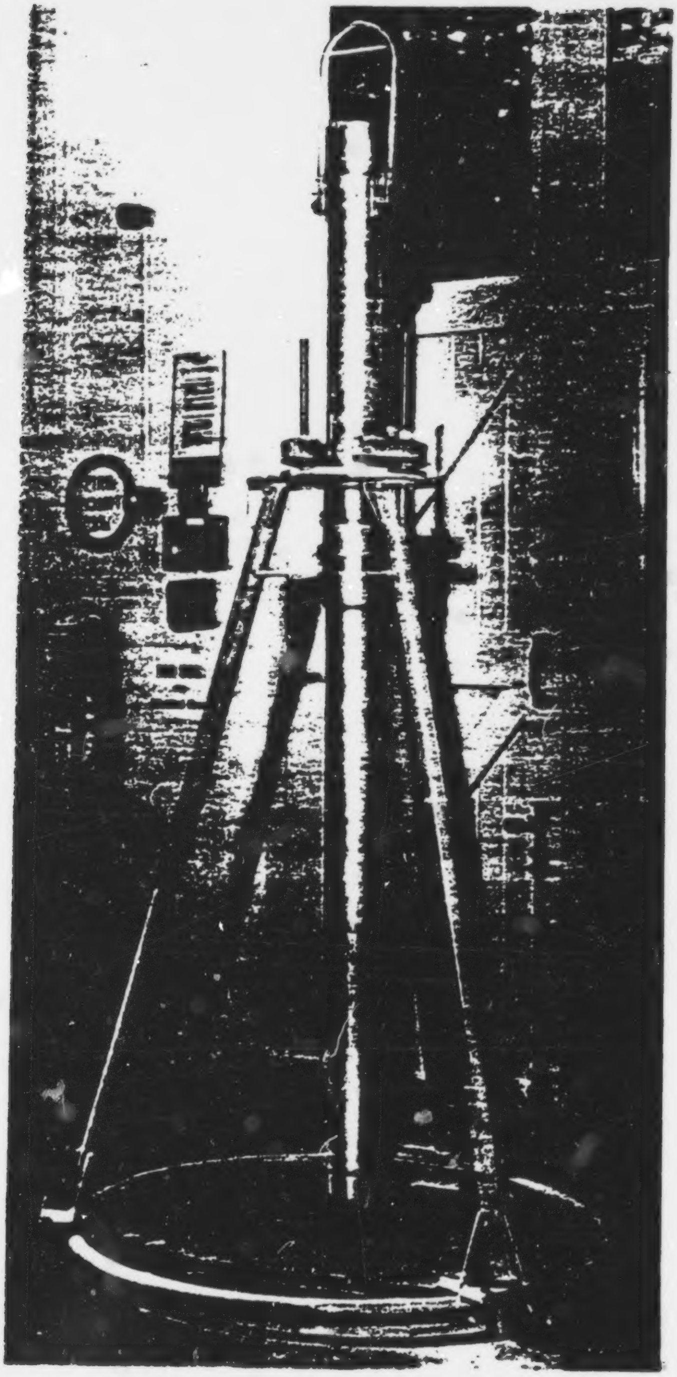


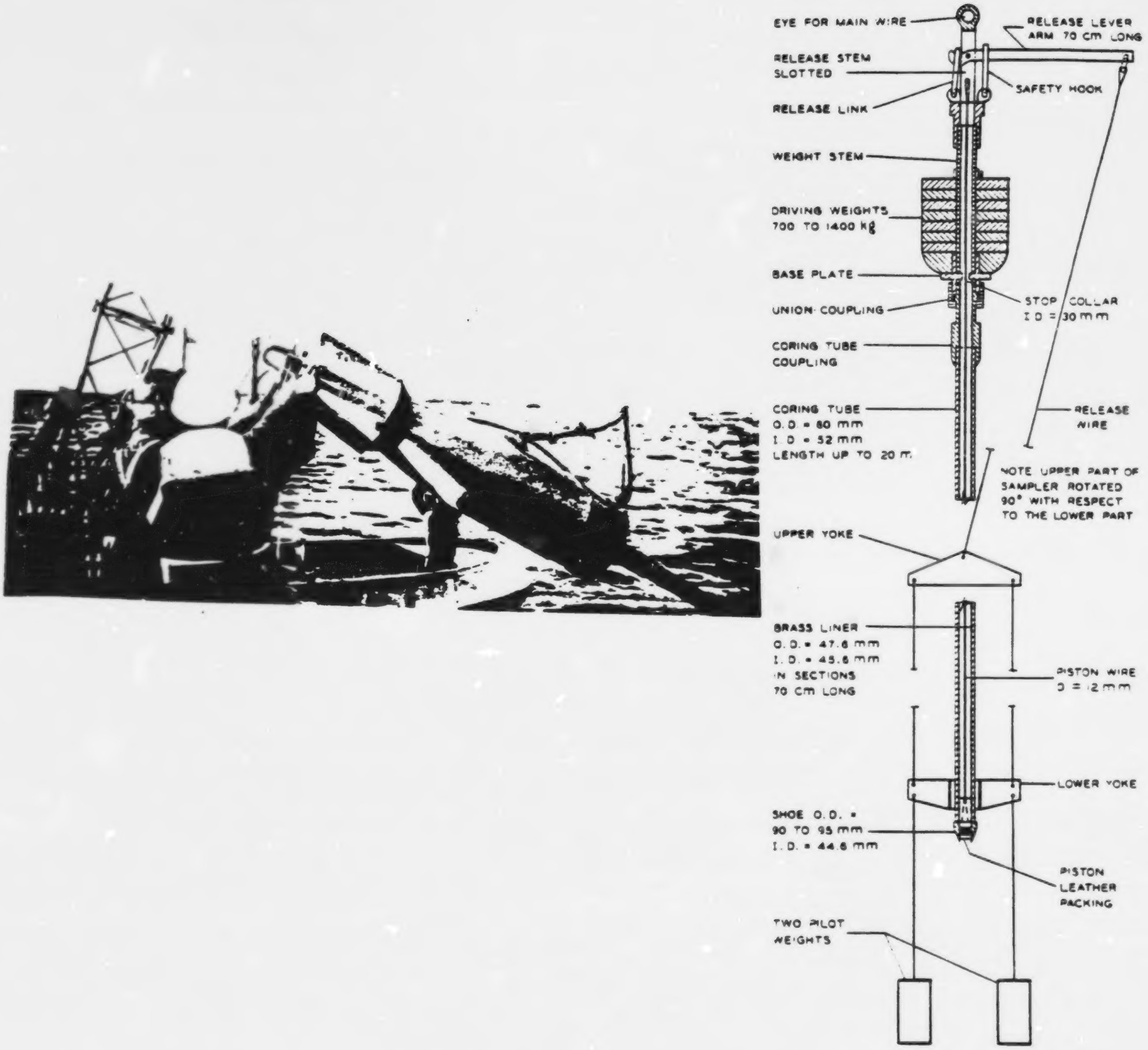
FIGURE 4.10 - I.O.S. Multi-Purpose Gravity Corer

4.2.10 Benthos Corer (Figure 4.11)

Developed by Benthos Inc., North Falmouth, Mass. (Benthos 1976).

This system is capable of recovering 66 mm diameter cores, 3 m long from sediment in water depths up to 6000 m.

The corer is a Kullenberg type with a release mechanism for freefall and weighs about 900 kg. An optional piston immobilizer assists core retention on retrieval and a pressure actuated safety arming pin prevents accidental triggering during deployment.


EYE FOR MAIN WIRE
RELEASE LEVER ARM 70 cm LONG
RELEASE STEM SLOTTED
SAFETY HOOK
RELEASE LINK
WEIGHT STEM
DRIVING WEIGHTS 700 TO 1400 kg
BASE PLATE
STOP COLLAR I.D. = 30 mm
UNION COUPLING
CORING TUBE COUPLING
CORING TUBE O.D. = 60 mm I.D. = 52 mm LENGTH UP TO 20 m.
RELEASE WIRE
NOTE UPPER PART OF SAMPLER ROTATED 90° WITH RESPECT TO THE LOWER PART
UPPER YOKE
BRASS LINER O.D. = 47.6 mm I.D. = 45.6 mm IN SECTIONS 70 cm LONG
PISTON WIRE D = 12 mm
LOWER YOKE
SHOE O.D. = 90 TO 95 mm I.D. = 44.6 mm
PISTON LEATHER PACKING
TWO PILOT WEIGHTS

B. KULLENBERG: THE PISTON CORE SAMPLER

Figure 4.11 - Benthos Corer

4.2.11 Long Coring Facility (Figure 4.12)

Developed by Graduate School of Oceanography, University of Rhode Island, R.I., 1981 (Driscoll 1981).

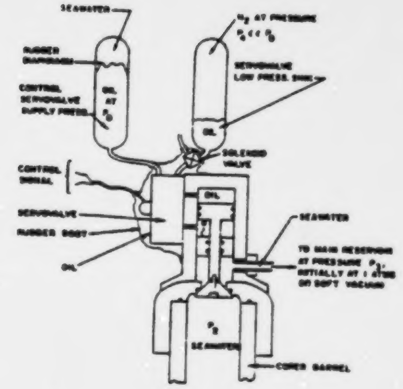
This system is capable of recovering 110 mm diameter cores, 50 m long from unconsolidated sediment in water depths up to 6500 m.

The unit is 55 m long and weighs between 12,900 and 15,400 kg. It consists of a step tapered barrel string assembly 120 mm I.D. The lower 15 m section has an O.D. of 146 mm, the middle 20 m section 171 mm O.D. and the upper 15 m section 222 mm O.D.

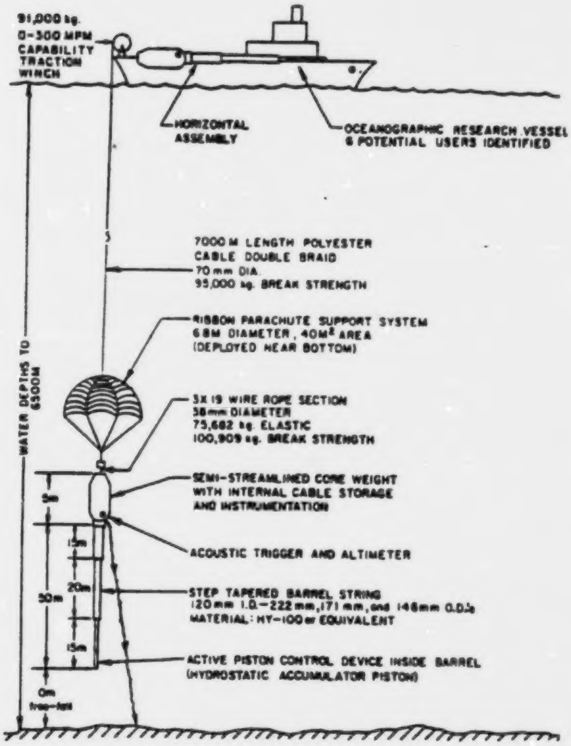
The top 5 m of the corer contains the core weight, internal cable storage and instrumentation. A ribbon parachute support system is deployed near the bottom by the use of an acoustic trigger which at the same time activates the freefall mechanism. The unit also utilizes such instrumentation as a recording altimeter, tilt sensor, rotation recorder and a hydrostatic accumulator piston.

The long coring facility can only be deployed from large oceanographic vessels such as the R.V. KNORR.

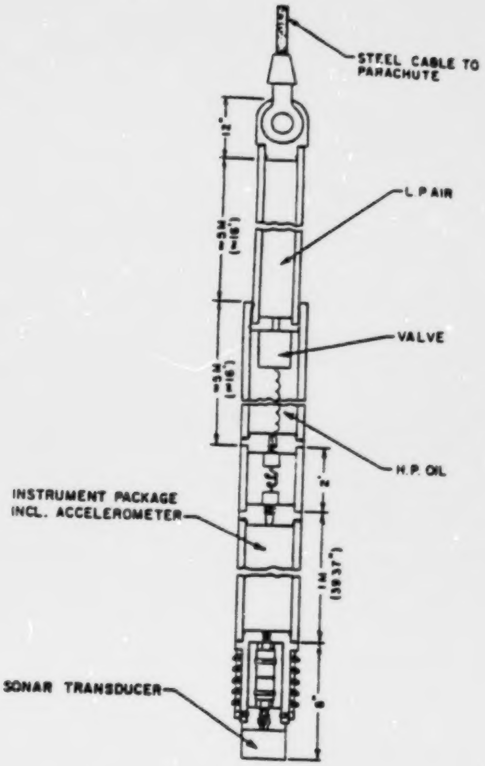
This equipment has not yet been constructed.


SEAWATER
RUBBER DIAPHRAGM
CONTROL SERVOVALVE SUPPLY PRESS.
OIL AT P_0
N_2 AT PRESSURE
$P_4 << P_0$
SERVOVALVE LOW PRESS. SINK
OIL
SOLENOID VALVE
CONTROL SIGNAL
OIL
SERVOVALVE
RUBBER BOOT
OIL
SEAWATER
TO MAIN RESERVOIR AT PRESSURE P_3, INITIALLY AT 1 ATMS OR SOFT VACUUM
P_2
SEAWATER
CORER BARREL

FREE ACTIVATING PISTON (FAP)


91,000 kg.
0-300 MPM
CAPABILITY
TRACTION
WINCH
HORIZONTAL
ASSEMBLY
OCEANOGRAPHIC RESEARCH VESSEL
6 POTENTIAL USERS IDENTIFIED
7000 M LENGTH POLYESTER
CABLE DOUBLE BRAID
70 mm DIA.
95,000 kg. BREAK STRENGTH
WATER DEPTHS TO 6500M
RIBBON PARACHUTE SUPPORT SYSTEM
6.8M DIAMETER, 40M² AREA
(DEPLOYED NEAR BOTTOM)
3X19 WIRE ROPE SECTION
38mm DIAMETER
75,682 kg. ELASTIC
100,909 kg. BREAK STRENGTH
5m
SEMI-STREAMLINED CORE WEIGHT
WITH INTERNAL CABLE STORAGE
AND INSTRUMENTATION
15m
ACOUSTIC TRIGGER AND ALTIMETER
50m
20m
STEP TAPERED BARREL STRING
120 mm I.D.—222 mm, 171 mm, and 146mm O.D.'s
MATERIAL: HY-100 or EQUIVALENT
15m
ACTIVE PISTON CONTROL DEVICE INSIDE BARREL
(HYDROSTATIC ACCUMULATOR PISTON)
0m
free-fall

LCF SYSTEM CONFIGURATION


STEEL CABLE TO PARACHUTE
12"
L.P. AIR
≈5M (≈16')
VALVE
≈5M (≈16')
H.P. OIL
2"
INSTRUMENT PACKAGE INCL. ACCELEROMETER
1M (39.37")
SONAR TRANSDUCER
6"

HYDROSTATIC ACCUMULATOR PISTON (HAP)

Figure 4.12 - Long Coring Facility

4.2.12 Long Hydroplastic Sediment Corer (Figure 4.13)

Developed by Marine Division, Geological Survey of Israel, Jerusalem, 1981 (Almagor and Argas 1981).

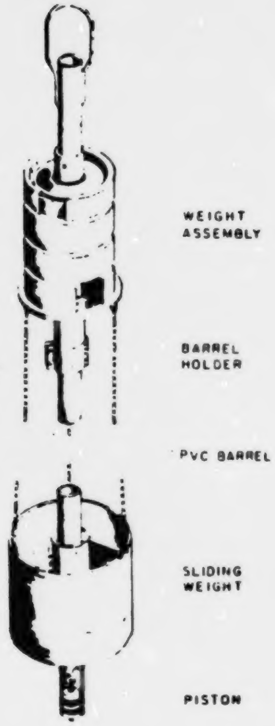
Based on the original design of Richards and Keller (1961).

This system is capable of recovering 80 mm diameter cores, 8 m long from silty clays in water depths up to 900 m.

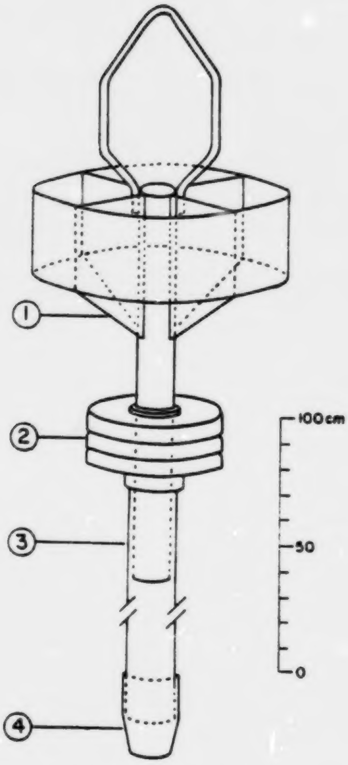
The unit is approximately 9 m high and weighs 200 kg. A 30 kg sliding weight is attached with 3 chains to the main body of the corer. The length of the chains allows the weight to stay 0.5 m above the tip of the PVC barrel. Placing the weight low on the barrel ensures vertical free fall of the corer.

The cohesive nature of the silty clays of the Mediterranean permits the 8 m long PVC tubes (90 mm o.d.) to be fitted without core bits, noses, core catchers or retainers. The corer is given a freefall of 2.5 - 3.0 m, and utilizes an immobilizing piston to ensure that the uppermost section of the sedimentary column is sampled.

This coring system has successfully been used at various locations in the southeastern Mediterranean.



Hydroplastic core sampler with sliding weight.



Hydroplastic corer. This is one of many basic designs of the gravity corer. These samplers are driven into the sediment by the weight of the device. The amount of weight (2) is usually adjustable. In this model, the barrel (3) is made of plastic (plastic liner from a piston corer is sometimes used). The barrel can be attached to the weight-stand with screws or hose clamps. The barrel length is variable, but usually less than 3 m. The nose piece (4) contains an annulus of slightly curved, spring-metal fingers which prevent the loss of the core sample upon pull-out. The prevention of sample loss is also aided by a check valve at the top of the core which allows water to flow through the barrel during descent, but closes upon retrieval.

Figure 4.13 - Long Hydroplastic Sediment Corer

4.2.13 Stacor (Figure 4.14)

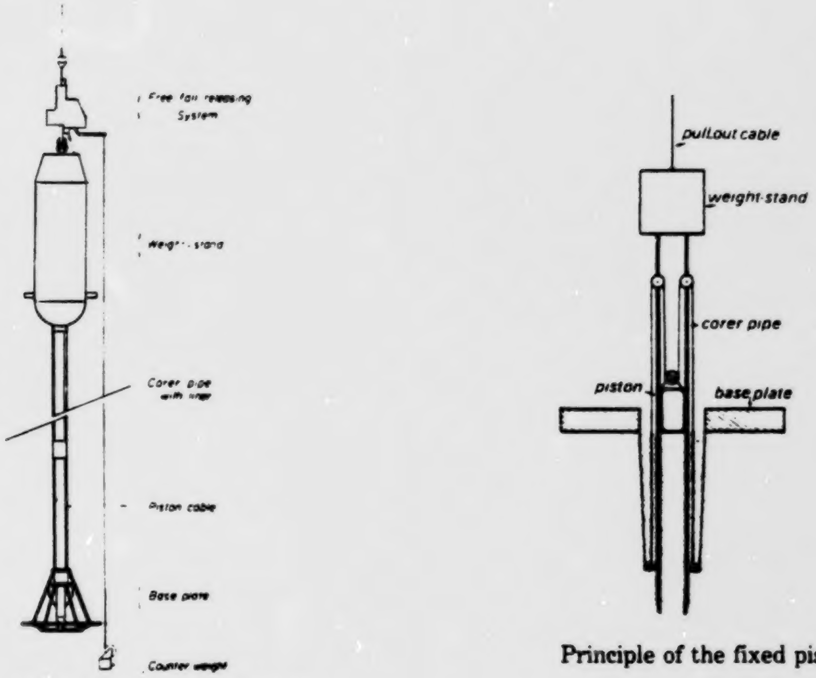
The Stacor is a free fall gravity corer with a fixed piston which was developed (c.a. 1982) by the Institut Francais du Petrole, France, in conjunction with Elf-Aquitaine and Total (Fay et al. 1985).

The unit is capable of taking soft sediment samples 110 mm in diameter up to 30 m long in 1,000 m of water and weighs up to 10 tonnes.

It consists of a core barrel 30 m long with a weight stand capable of holding up to 5.5 tonnes of ballast. It uses a fixed piston in the core tube while pentrating the soil to provide relatively undisturbed samples. The corer is allowed to free fall into the seabed once it has been lowered to a predetermined distance above the seafloor. At this point a counter weight contacts the ocean floor releasing the corer.

Core retrieval relies on the shipboard winch in conjunction with an A-frame over the stern of the vessel. The hoisting system must be capable of supplying between 10 tonnes and 60 tonnes of lift.

The equipment was successfully tested in the Gulf of Lions, France, in April 1982 and May 1983 from the "Nadir" in 50 m to 1,225 m water depths. It is understood that in 1985 the system was used to recover 30 m long cores in water depths of nearly 6,000 m (Richards 1986).


Free fall releasing System
Weight - stand
Corer pipe with liner
Piston cable
Base plate
Counter weight
pullout cable
weight-stand
corer pipe
piston
base plate

Description of the STACOR

Principle of the fixed piston

Figure 4.14 - Stacor

4.3 VIBRATORY CORERS

As an alternative to gravity corers, Russian engineers began soil sampling by vibration drilling methods around 1950, but it was not until 1963 that electrically driven vibratory corers were first developed in North America. Since then numerous types of vibratory corers have been developed. Many vibrocorers operate as units on the seafloor, remotely controlled from a surface ship through a power cable which may also serve to lower the unit to the seafloor. The unit is switched on after being lowered to a stable, vertical, position. The basic principle is that the power source imparts high frequency vertical vibration to the core barrel and this results in penetration of the sampler into soil. At appropriate vibration frequencies the sediment adjacent to the corer becomes thixotropic and acts as a lubricant thus aiding penetration of the sample tube. In one arrangement the power source is electric and paired eccentric weights are rotated in opposite directions so that their forces add in the vertical direction and cancel in the horizontal. Other systems are of the pneumatic percussive type in which a piston-hammer is driven up and down on top of the core barrel using an arrangement of pressurized air, a core head valve and a spring to produce only vertical forces. Vibrocorers developed to date have various amplitudes and frequencies of vibration. Electric powered vibrocorers have vibration frequencies of 100 - 4000 cycles/sec while pneumatic vibrocorers vibrate at 10 - 40 cycles/sec.

Vibrocorers can usually recover cores 4-6 meters long from sand, which is an unconsolidated cohesionless material; however, very little success has been achieved using vibrocorers to take cores of stiff clay, gravel or mixtures of soil where there is a low percentage of sand, or in soils containing larger stones which can cause core barrel blockage.

The following vibrocorers were considered in this study. Further details of these systems are given in Table 4.2. Addresses of selected equipment manufacturers are given in Appendix A.

TABLE 4.2 VIBRATORY CORERS

SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
1. BGS-Aimers McLean Vibrocorer	Boulder, clay, overconsolidated sediment, sand, gravel	1000 m	3m / 63mm 3m / 114 mm 6m / 63 mm 6m / 114 mm	1860 kg. (6-meter version)	6.9 m/ 6.0 m	Inclinometers and penetrometer	20KVA, 3PH at 415V via a separate umbilical	Yes	Recent modifications allow combinations of rotary and vibratory coring. Used in sea states 6/7. Has been used extensively on the UK continental shelf.
2. VIET-KOGLER German Vibro-Hammer (Kiel University VIBRO CORER)	Sand, Unconsolidated Sediments	400 m	3m/15 cm sq. 6m/15 cm sq.	600 kg.	7 m/ 2.6 m	Inclinometers and penetrometer	5 kw, 3 ph at 380V via separate umbilical	Yes	Has been used successfully off West Africa and in the Baltic and North Seas.
3. U.S. Geological Survey, Portable Hydraulic Vibrocorer	Unconsolidated Sediments, clay	34 m	5.4m/75 mm	225 kg.	8.1 m/ 6 m	No Instrumentation	Unknown	No	Hydraulic jackhammer for shallow work only. Can be operated from a small vessel (10.5m length) by 4 people with the aid of scuba divers.
4. U. of Rhode Island Vibrocorer	Unconsolidated sediments, sands	200 m	2m / 65mm	1000 kg.	3 m/ 2 m	No Instrumentation	Uses 12V silver cell, rechargeable batteries activated when suspending cable tension is released.	No	Can take three cores simultaneously. Had poor sample recovery from the R.V. Trident off New Jersey. Suspected due to precompressed clays, low vibration times and several equipment failures.

TABLE 4.2 CONTINUED

SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
5. U of Miami Portable Vibrocorer	Unconsolidated sediments, clay, silt, very coarse sand	18 m	13m / 30mm 13m / 60mm	150 kg.	Unknown	No instrumentation	Uses a 7 hp gasoline engine to direct drive a commercial vibrator	No	Can be handled by 2 people in a small boat. Has been successfully used in the Bahamas, South America, Western Australia and the Southern United States. Water depths beyond 10m require use of divers.
6. Geodoff I	Alluvial Formations	150 m	8m / 60mm	2500 kg.	5.6 m/ 2.3 m	Inclinometer, Penetrometer	7.5 kw electrical power. Unknown voltage	Yes	A variable frequency vibrator is used. Counterflush, airlift and rotary table are options. It has been successfully used in the North Sea and the Indian Ocean.
7. Geodoff I Mark II	Unconsolidated sediments	200 m	7m / 150mm	4800 kg.	5.6 m/ 2.4 m	TV camera to monitor inclinometer, vibrator/rotary table travel core barrel clamping force, pull down and pull-up forces and system hydraulic pressure.	15 KVA to power hydraulics for rotary table. 5 KVA to power electric vibrators. Unknown voltage.	Yes	Uses a combination of vibratory and rotary coring. Counterflush and airlift systems are options.

TABLE 4.2 CONTINUED

	SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
8.	V.4.S.8 Vibrocoring Device (B.R.A.M.)	Mixtures of sands, gravels and pebbles	450 m	3m / 100mm 5m / 125mm 8m / 200mm	1000 kg. to 1600 kg.	9 m/ 1.0 m	Penetration Sensor	12 KVA at 380V, 50Hz via a separate umbilical	No	Can be used from a non-specialized vessel that has hauling tackle. Has been used successfully in Senegal, Nigeria, Scotland and Martinique.
9.	Seabed Rokleng Air Hammer	Unconsolidated sediments	100 m	5m / 100mm 5m / 160mm 5m / 170mm	900 kg.	6.45/ 5.0 m	Inclination indicator, penetration sensor	Pneumatically driven using 1.5m^3/min at 6 bar.	No	Vibrohammer slides on 2 vertical pillars. Hydrohammer version under development.
10.	Seabed Vibrocorer SVC 500 E SVC 500 ETR	Soft cohesive soils, sediment	300 m	5m / 100mm	750 kg.	SVC 500 E 6.4m / 5.0m SVC 500 ETR 6.35m/ 6.0m	Penetration indicator.	Two synchronized vibrator motors 2.2 kw each (4.4 kw total) at 380V, 3-phase, 50 hertz.	No	SVC 500 ETR has been optimized for ease of transport. Surface electronics have been containerized.
11.	Geomarex Vibrocorers P_1 P_4 P_6 P_{10}	Unconsolidated Sediments	500 m	P_1 6m/75mm 90mm 100mm P_4 6m/100mm P_6 6m/165mm P_{10} 6m/250mm	P_1 110kg P_4 275kg P_6 275kg P_{10} 275kg	7m / 1.0m	None	P_1-1.5 kw at 110 VAC/DC P_4-3.0 kw at 220 VAC, 3-phase 60 hertz P_6 & P_{10} - unknown but larger requirements than P_4	No	Float package is used to orient core tube. Water jetting and reverse circulation options are available.
12.	Mackereth Portable Core Sampler	Soft sediments	250 m	6m / 38mm	400kg	7.5m / 0.5m	No instrumentation	Compressed air from surface generator. Power consumption unknown	Yes	Can be used by two men in a rowboat. It used a buoyance lift to the surface and is very portable

TABLE 4.2 CONTINUED

	SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
13.	Marex Vibrocorer	Fine sand, clay	Unknown	3.9m / 63mm Much shorter core lentghs are obtained in gravel	1400 kg	6.8m / 4.5m	Information not available from references	Two 3½ hp motors supplied at 110 V, 3 phase and 50Hz	Unknown	
14.	HAAMER Vibrocorer	Unconsolidated sediments	80m	5.5m / 57mm 12m / 81m	480 kg.	6m / 2m	Motor current, water jet pressure	Two vibrator motors requiring total of 2.9 KVA at 380 V, 3 phase, 50 Hz. Water for water jet supplied by support vessel at 40 bar and 40ℓ/min.	No	Force from 2 synchronized vibrators and a guiding buoy. Reduce core disturbance by encasing it in a plastic foil as it enters core barrel. Can be used from a small trawler or vessel. Used successfully in Sweden.
15.	Alluvial Mining Vibrocorer	Unconsolidated sediment, sand gravel and clay	100 m (250 m for hydraulic version)	4m / 85mm 6m / 100mm 8m / 150mm 10m /	1850 kg to 2150 kg (2800 to 3800 kg. for hydraulic version)	Varies with unit required. For 6m version, 7.8m / 6m	Voltage, current, penetrometer (acoustically linked)	Two vibrator motors requiring total of 6 hp at 440 V, 3 phase, 50 Hz	Yes	Water jetting is available as an option. Similar units are available which operate on the "vibrohammer" principle, powered electrically, hydraulically or pneumatically.
16.	Alpine Vibracorer	Stiff clays, sands and gravel	300 m	12m / 89mm	1800 kg.	14.1m / 6.0m	None	250 cubic ft. per min. of air at 120 p.s.i.	No	Pneumatically driven with return hoses so that air is exhausted at atmospheric pressure. Used extensively by the U.S. Army Corps of Engineers.

TABLE 4.2 CONTINUED

	SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
17.	Wink Vibrocorer	Unconsolidated sediment	Depends on maximum height of unsupported drill-string possible	6.7m / 50mm	36 kg. (excluding drill-pipe)	Depends on no. of drill rods used	None	Direct driven from an 8 hp gasoline engine	No (Support ship retracts)	Developed for land use. Direct control system. Drill rods must extend above water line. Vibrator unit mounted on top of drill string above water. Used successfully in Nova Scotia for placer evaluation.
18.	Horton Vibrocorer	Unconsolidated gravel, sediment, and sand	63 m	30m / 152mm	Unknown and Variable	Over the side derrick required approx. 4.5m high.	None (Direct control from surface)	Unknown	No (Support ship retracts)	Manufacturer out of business Required over the side derrick 4.5m high. Vibrator head moved up pipe as penetration achieved. Sensitive to lateral ship motion.
19.	Geomarex Hummingdrill Vibrocorer	Unconsolidated and/or water-logged sediment	Depends on maximum hgt. of unsupported drill string & lift capabilities of vessel	5.5m / 89mm	11.4 kg (excluding drill pipe)	Depends on no. of drill rods used	None (Direct control from surface)	Direct driven via flexible cable from a 5 hp gasoline engine	No (Support ship retracts)	Similar to Wink. Direct control system. Developed for land use but can be adapted for over water. Water jetting an available option. Not been used over water to date.

TABLE 4.2 CONTINUED

SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
20. Dutch Geological Survey Roflush II	Unconsolidated sand, clay, sediment, and gravel	Unknown but probably less than 100 m	Unknown penetrations 90 mm I.D. Continuous sampling	1000 kg.	Unknown	Unknown but expected to be little	Air powered but requirements unknown	Unknown	Air hammer drives double wall pipe. Continuous reverse flush sampling to surface. Unit still under development.

4.3.1 BGS (IGS) - Aimers McLean Vibrocorer (Figures 4.15 and 4.16)

Developed by the British Geological Survey (BGS - formerly the Institute of Geological Sciences, U.K.), in 1971 and constructed by Aimers McLean (Ardus et al. 1982, Birch 1977, Kirby 1972). Aimers McLean have recently gone out of business and production of this unit has virtually stopped although some units may still be available from BGS. The Atlantic Geoscience Centre at Bedford Institute of Oceanography uses a modified Aimers McLean Vibrocorer on some of its surveys.

The Aimers McLean Vibrocorer is capable of taking 63 mm and 114 mm diameter cores in lengths of 3 and 6 m in water depths up to 1000 m.

The 6 m model consists of a tubular frame 6.9 m high supported by three legs with radius 2.9 m, weighing 1860 kg in air. The 3 m version is a similar configuration 3.9 m high with a base radius of 1.8 m, weighing 1,380 kg.

Contained within the framework are the vibrator head, power distribution box, electro-hydraulic power pack, hydraulic retraction winch, tilt indicators and acoustic penetration measurement transducer. The retraction winch removes the corer at 1.5 m/min with a steady pull of up to 12 tonnes.

The electric vibrator is directly mounted on the core barrel and linked by a power lead to the junction box. It comprises a pressure vessel, housing a twin linear vibration motor.

Twenty kVA, 415V, 3 phase power is supplied from the support vessel via a separate umbilical cable. This cable also provides power and signal return for tilt indicators and penetrometer.

The corer is designed for a toboggan launch commencing in a horizontal position on deck and pivoting over the platform edge into the sea. The launch and recovery procedures have been safely completed in sea states up to 6 to 7 (Beaufort Scale). The equipment designer, however, feels that if it is to be used from a small fishing boat (200 t/30 m) sea states would have to be nearly flat calm (Pheasant 1986).

The Aimers McLean Vibrocorer has successfully been used in the North Sea since 1971 to aid BGS in the geological survey of the U.K. continental shelf.

Recent (c.a. 1983) modifications to the vibrocorer (Pheasant 1984) have incorporated rotary drilling features within the framework of the existing system (Figure 4.16).

The rotary table is electro-hydraulically driven up to 600 rpm. An additional 15 HP motor has been added to power this equipment. Two 17 stage centrifugal saltwater drill flush pumps have been provided, each powered by a 1 HP, 50 Hz, 3 phase motor.

It is capable of sampling through up to 5 m of overburden before taking a one meter rockcore. The core diameter has been reduced to 45 mm.

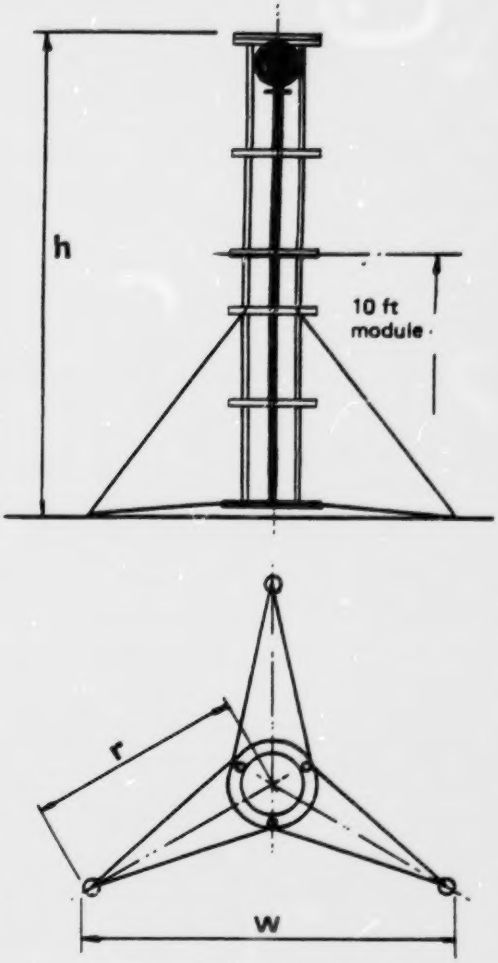
Combined vibratory and rotary drilling techniques have increased penetration speeds and depths although complete failure of tungsten carbide bits have resulted. This problem was overcome using surface set diamond bits.

The following are approximate lease costs for the vibrocorer (Richards 1986).

	British Pound	Approximate equivalent Canadian Dollars (1986)
Consumables/site	85	170
Drill Site Charge	35	70
Mobilization (in U.K.)	2,000	4,000
Demobilization (in U.K.)	1,000	2,000
Equipment Operation	410/day	820
Equipment Standby Rate	110/day	220
Operator (1 for vibrocorer, 2 for rockdrill)	210/person-day	420

Dimensions	10' Module	20' Module
Height (h)	12' 10" (3906)	22' 7" (6890)
Radius over feet (r)	6' 0" (1829)	9' 6" (2896)
Width over feet (w)	10' 4" (3251)	17' 0" (5176)
Weight (including motor)	3038 lb (1379 kg)	4102 lb (1860 kg)
Power required	20 kva 415v 3 phase	

Sample size: 2½"(63) or 4"(114) nominal dia in 10' 0" (3 metre) or 20' 0" (6 metre) nominal tube lengths.



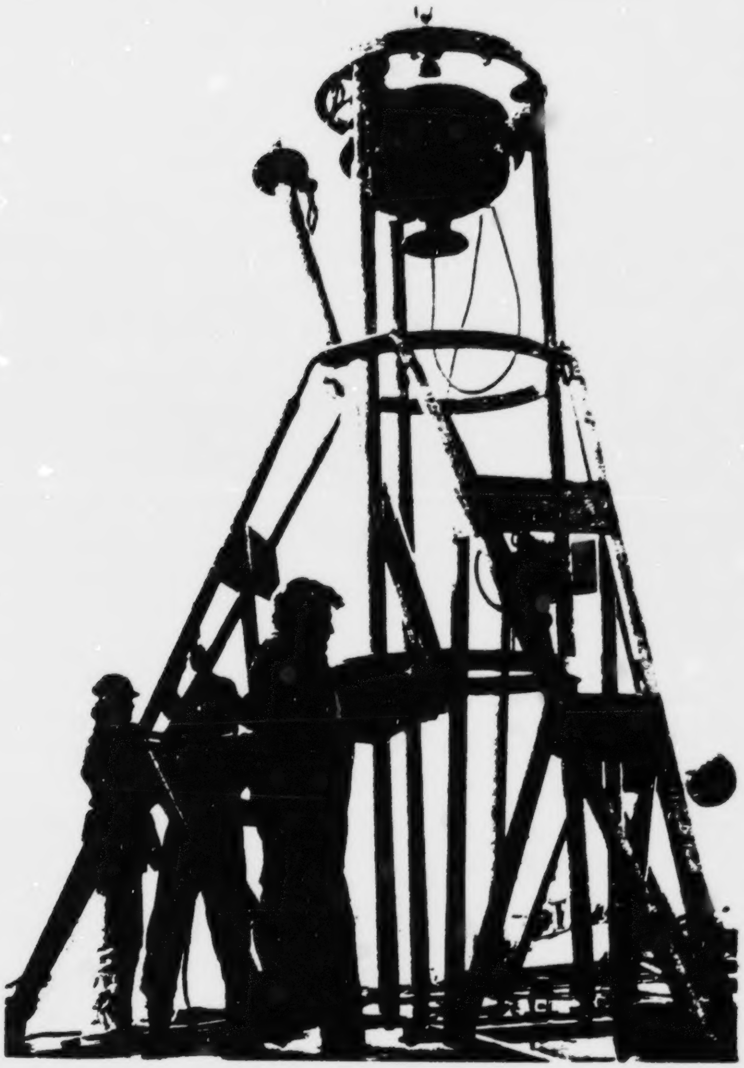


FIGURE 4.15 - BGS - Aimers McLean Vibrocorer

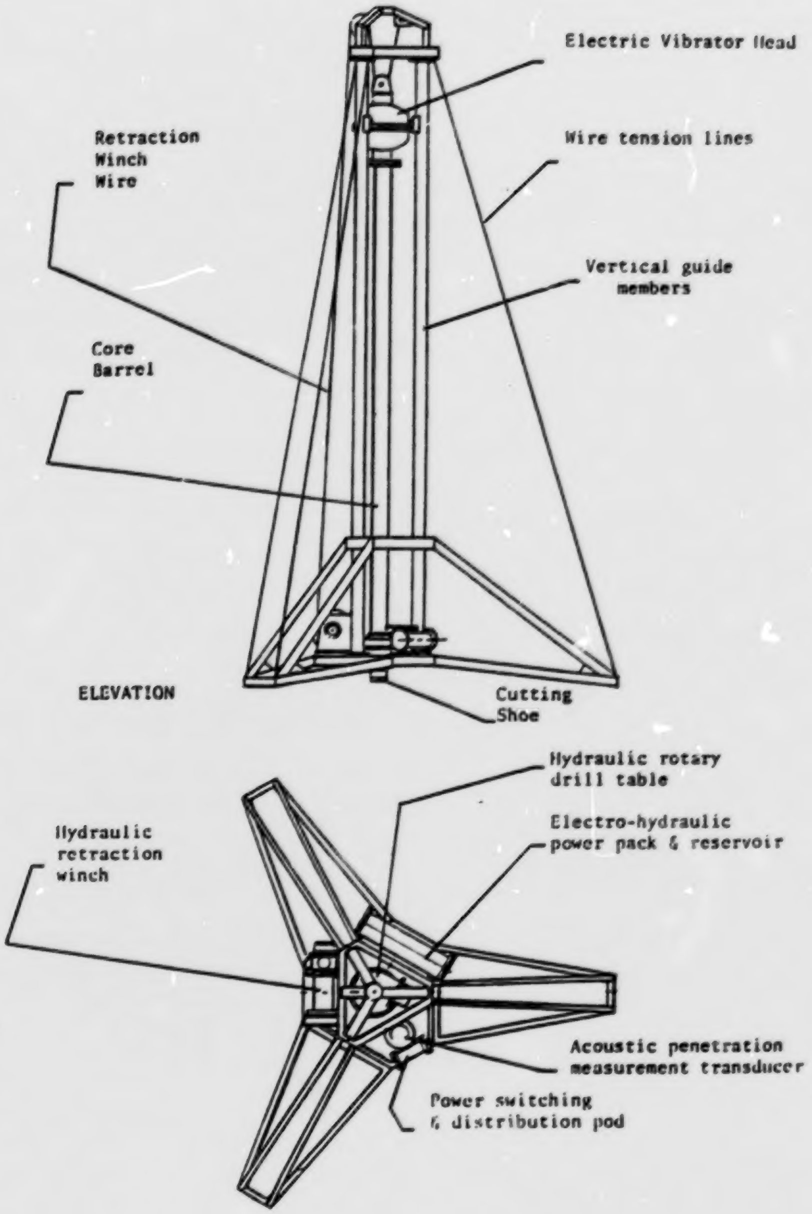

Electric Vibrator Head
Retraction Winch Wire
Wire tension lines
Vertical guide members
Core Barrel
ELEVATION
Cutting Shoe
Hydraulic rotary drill table
Electro-hydraulic power pack & reservoir
Hydraulic retraction winch
Acoustic penetration measurement transducer
Power switching & distribution pod

Figure 4.16 - BGS - Aimers MacLean Vibrocorer/Rotary Drill

4.3.2 Viet - Kogler (VK) Kiel University Vibrocorer (Figure 4.17)

Developed by Kiel University, Kiel, W. Germany, 1971 (Kogler and Veit 1973).

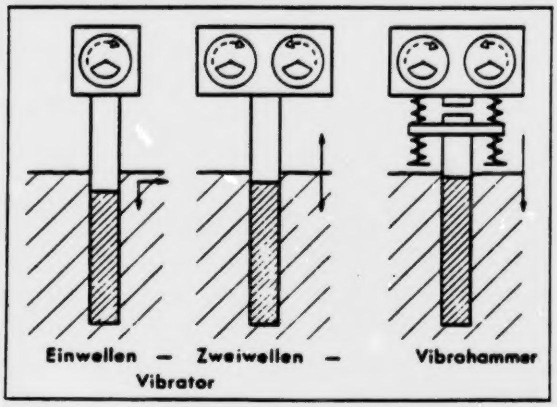
Manufactured by Hydrowerkstatten, Kiel, W. Germany.

The VK vibrocorer is capable of taking 150 mm x 150 mm box cores in 3 and 6 m lengths. The system is suitable for use in unconsolidated sediment in water depths less than 400 m.

The 6 m model consists of a 7 m high frame with a 2.6 m square base. The system weights 600 kg in air.

The VK vibrocorer employs a technique of vibrohammering. Power is supplied from the support vessel at 5 kW., 380 V, 3 phase to drive the vibrator motor, retract winch and the various sensors. A separate umbilical is used complete with signal return for the inclinometers and penetrometer.

This corer has successfully been used off the coast of west Africa in 1971 and more recently in the Baltic and North Seas.


Einwellen – Zweiwellen –
Vibrator
Vibrohammer

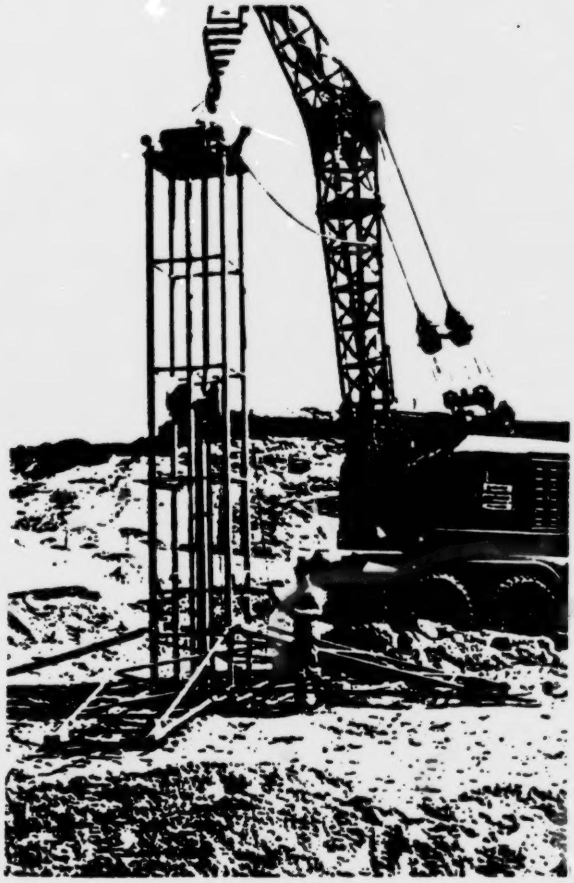


Figure 4.17 - Viet-Kogler Kiel University Vibrocorer

4.3.3 U.S. Geological Survey, Portable Vibrocorer (Figure 4.18)

Developed by the U.S. Geological Survey, Texas, 1979 (Dokken et al. 1979).

This system is capable of taking 75 mm diameter cores, 5.4 m long, from unconsolidated sediment, in water depths up to 35 m.

The unit consists of a tripod constructed of aluminum pipe, 8.1 m high with three legs having a radius of 3 m. It has a weight of 225 kg in air.

This corer uses a standard hydraulic jackhammer as its driving mechanism and is unique in that 4 people, with the aid of scuba divers, can operate the equipment in a boat as small as 10.5 m. The system is dismantled into three components: 1) legs with braces and foot pads; 2) guide track with lifting insert; and 3) jackhammer and compressor with holes. Apart from the compressor all items are assembled underwater by scuba divers.

The average time for complete core barrel penetration is 15 minutes. Upon completion, the corer is pulled out using the same winch for raising and lowering. Assembly and disassembly of unit requires 40 minutes.

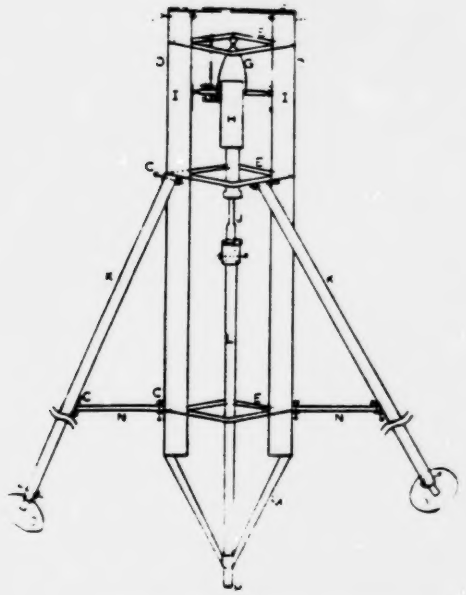
The materials to build the unit cost $6,000 U.S. (1977).

The unit has been used successfully off the coast of St. Thomas and the U.S. Virgin Islands to sample calcareous sediments and off Matagorda Island in Texas to sample sand and clay layered sediment.

The system does not have a core retract winch and problems have been encountered with bending of core barrels when the ship is not directly above the sampler during retraction operations.

It is not clear whether divers are essential to operate the system but, if so, this is a definite disadvantage in the present context.

It would appear that the system has not been used for sampling unconsolidated gravels.



Schematic diagram of the vibracore. Individual components are: a) winch wire, b) lifting insert, c) holding pins, d) guide track, e) guide track braces, f) hydraulic hoses, g) jackhammer bridle, h) hydraulic jackhammer, i) guide plates with casters, j) hammer core barrel couplet, k) legs, l) core barrel, m) core barrel guide, n) leg braces, o) foot pads, and p) core catcher assembly. Hydraulic compressor not shown.

Figure 4.18 - U.S. Geological Survey Portable Vibrocorer

4.3.4 University of Rhode Island Vibrocorer (Figure 4.19)

Developed by the Graduate School of Oceanography University of Rhode Island, R.I., 1971 (McMaster and McClennen 1973).

This system is capable of taking 3 simultaneous side-by-side cores, each 65 mm in diameter and 2 m long. Cores can be taken from unconsolidated sediment in water depths up to 200 m.

The system consists of a triangular platform that measures 2 m along the base and stands 3 m high. It has a total weight in air of 1000 kg.

Each vibration unit consists of two automotive starter motors geared to turn synchronized oppositely rotating eccentrics. These units are powered by three rechargeable 12 volt silver cell batteries. An electrical switch in the battery-vibrator circuit automatically activates the vibration mechanism when tension is released on the suspending cable.

This unit was tested in 1971, on the U.S. continental shelf off the coast of New Jersey from the research vessel R/V Trident. Thirteen stations were cored in water depths between 35 to 150 m. Penetration ranged from 200 mm to 1.8 m with vibration times at each station ranging from 30 seconds to over 2 minutes. Factors contributing to the low depth of penetration at some locations were the presence of dense sea scallop shell layers and "pre-compressed" clay deposits.

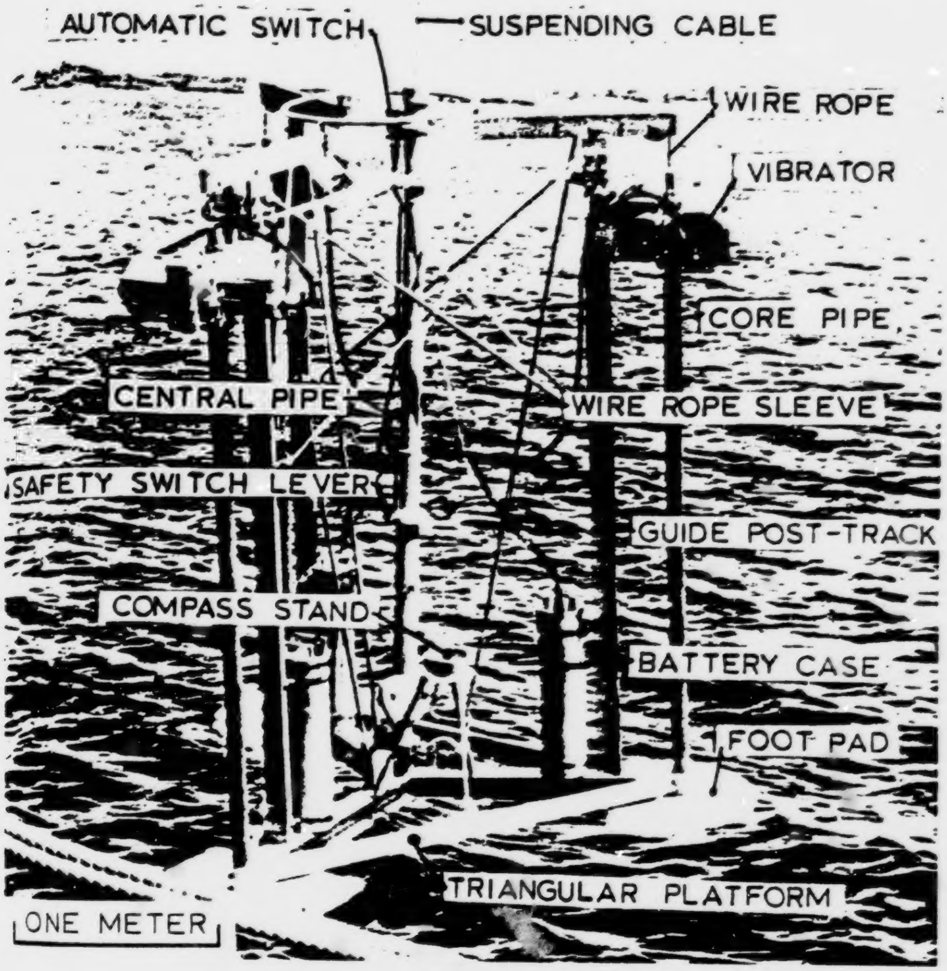

AUTOMATIC SWITCH
SUSPENDING CABLE
WIRE ROPE
VIBRATOR
CORE PIPE
CENTRAL PIPE
WIRE ROPE SLEEVE
SAFETY SWITCH LEVER
GUIDE POST-TRACK
COMPASS STAND
BATTERY CASE
FOOT PAD
TRIANGULAR PLATFORM
ONE METER

Figure 4.19

University of Rhode Island Vibrocorer

4.3.5 University of Miami Portable Vibrocorer (Figure 4.20)

Developed by University of Miami in conjunction with University of Western Australia and University of North Carolina at Chapel Hill, 1979 (Lanesky et al 1979).

This system is capable of taking 30 and 60 mm diameter cores up to 13 m long from unconsolidated sediment, particularly clay, silt, very coarse sand with pebble sized intraclasts and aggregates. It has a limited operating water depth of 18 m.

This vibracore is driven by a commercially manufactured grinder - concrete vibrator which is powered by a standard 7 hp gasoline engine via a flexible drive cable. Its light weight (150 kg) permits handling by two or three people in a small boat.

On land a hoisting tripod is usually rigged using several 9.2 m aluminum core barrels.

It appears that in water depths between 10 - 18 m, divers are needed to stabilize the core barrel. Cores have been obtained in water depths up to 10 m without divers. No rigid frame has been incorporated into the design.

When using the 18 m long flexible drive cable, a noticeable drop in engine speed indicating power loss due to friction has been noted. It is uncertain what effects additional lengths would have.

Approximately 200 cores averaging 4-6 m in length have been recovered in the coastal areas of the Bahamas, Suriname (South America), Western Australia, Florida, North Carolina, Southeast Texas and Southeast Louisiana. In some cores recovery was less than 75 percent and was attributed to plugging of the core tube by large shells or clasts.

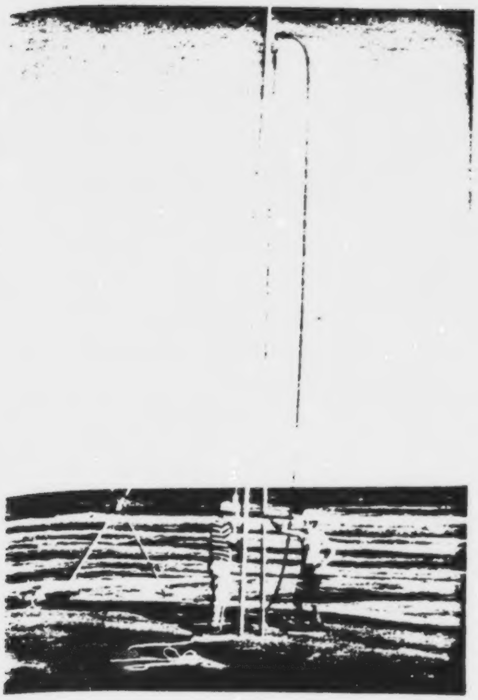


FIG. 1.—Core tube in position to begin coring showing hoisting mast and vibrator (Tripod not shown).

Figure 4.20 - University of Miami Vibrocorer

4.3.6 Geodoff I (Figure 4.21)

Developed by Conrad-Stork in co-operation with the Dutch Governmental Geological Service (Conrad-Stork 1969).

This system is capable of taking 60 mm diameter cores 8 m long from alluvial formations using two strokes of the vibrator. It has a maximum operating water depth of 150 m.

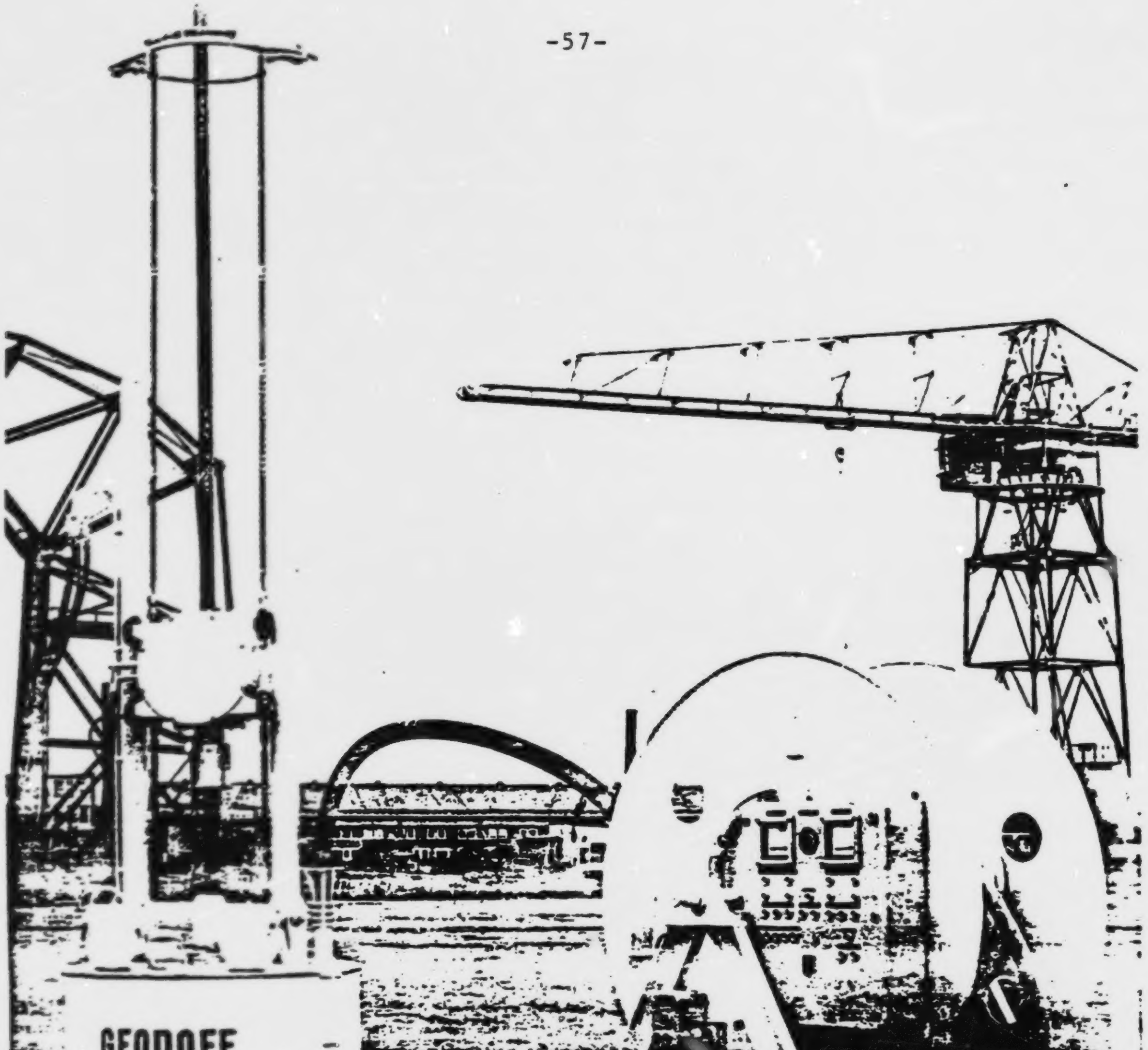
The Geodoff I consists of a tubular frame 5.6 m high with a circular base 2.3 m in dia. It has a weight of 2500 kg in air and 1300 kg underwater.

To accomodate various soil types, core barrel penetration is achieved with a variable frequency vibrator motor, 0-3500 cycle/min. Power for this 7.5 kw motor, the retract winch and sensors is supplied from the support vessel via a separate umbilical. The sensors consist of inclinometers and a penetrometer, these enable continuous monitoring of the coring operation and provide the necessary information to determine optimal vibrator frequency.

The Geodoff I has successfully been used in the North Sea and Indian Ocean.

Several other options are available. A counter flushing airlift system is available for use with the vibrocorer. This system continuously returns the soil to the surface and has achieved penetrations of up to 15 m while prospecting for tin in alluvial deposits.

Other options include a rotary corer module and a cone penetrometer for in situ geotechnical measurements.



General view of Geodoff I with cable drum and control panel

Figure 4.21 - Geodoff I

4.3.7 Geodoff I Mark II (Figure 4.22)

Developed by Conrad-Stork in co-operation with the Dutch Governmental Geological Service, and now marketed by Arkana Europe b.v., of Emmeloord, The Netherlands.

This system is capable of taking 150 mm diameter cores 7 m in length from unconsolidated sediment. It has a water depth capability of 200 m.

The Mark II consists of a tubular frame 5.6 m high with a circular base 2.4 m in diameter (4.5 m when legs are extended). It has a weight of 5530 kg in air and 2830 kg in water (Conrad, Undated).

The system uses a combination of electric and hydraulic equipment for its coring mechanism. A 20 hp (15 kVA) electric motor for hydraulic equipment and 10 hp (5 kVA) electric vibrators. Power is supplied from the support vessel via a separate umbilical. A retraction winch is a standard feature and instrumentation such as inclinometer; vibrator/rotary table travel indicator with counting device; manometers indicating the hydraulic pressure of the system; the clamping force of the core barrel clamp and the pulldown and pull up forces, is made visible by a closed television circuit which makes video recording of the complete drilling operation possible.

The system is an extension of the Geodoff I and has the same additional features. A counter flush system, rotary corer module and cone penetrometer are options.

The 1986 purchase price of the Geodoff I Mark II system, including 200 m of cable, is quoted as about $315,000 Canadian (Arkana 1986).

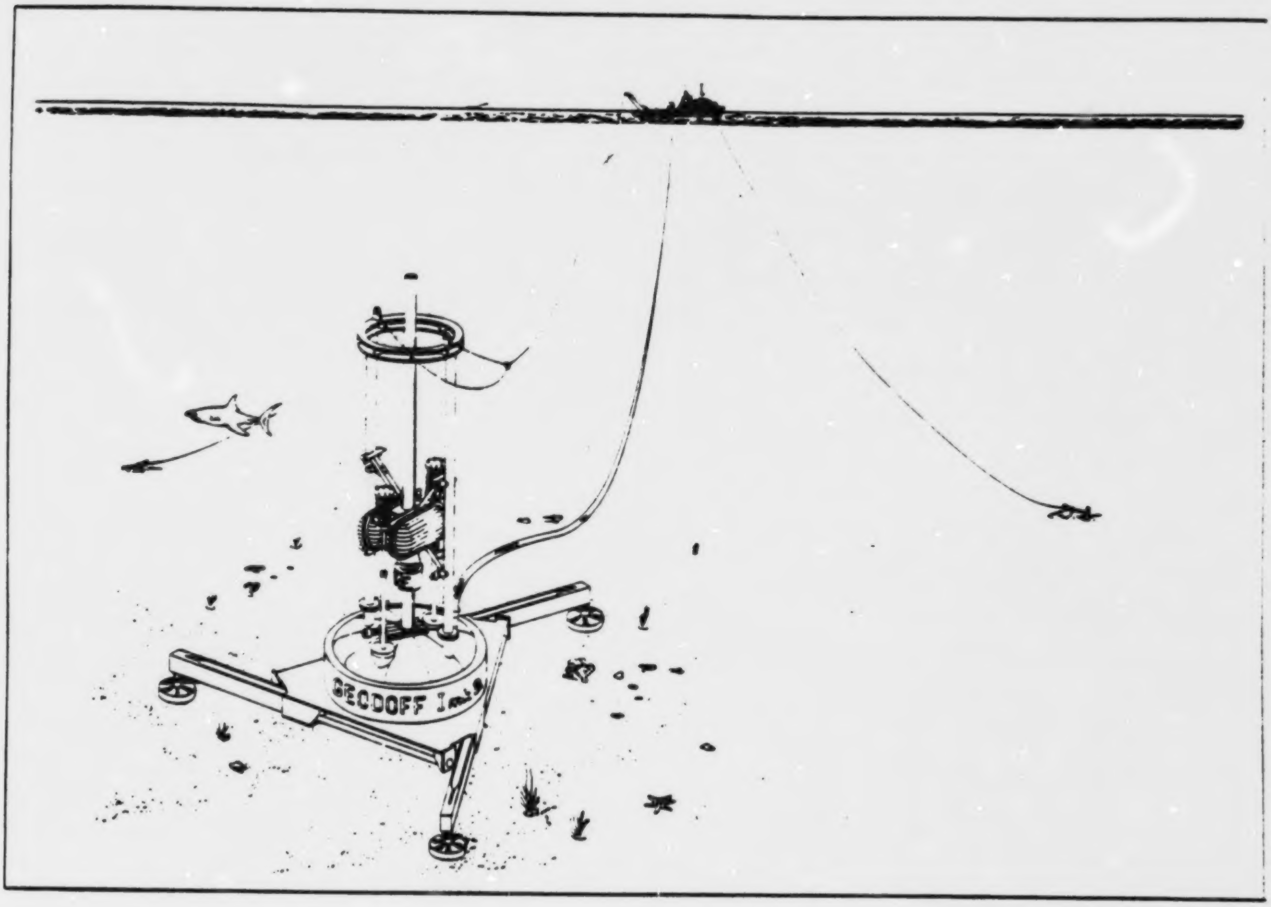

GEODOFF I mk2

FIGURE 4.22 Geodoff I (Mark 2) Vibrocorer

4.3.8 V.4.S.8. Vibrocoring Device (BRGM) (Figure 4.23)

Developed by Bureau De Recherches Geologiques et Minieres, France, 1972 (BRGM 1986).

This system is capable of taking 200 mm, 125 mm, and 100 mm diameter cores, 3, 5, and 8 m in length from sediment consisting of sands, gravels and pebbles. It has a water depth capability of 450 m.

The V.4.S.8 consists of a tubular frame with a rectangular base. In air the unit weighs from 1,000 kg to 1,600 kg depending on the length of core required.

The drive mechanism is provided by an electric vibrator motor. Power is supplied from the support vessel via a seperate umbilical at 12 kVA, 380 V, 50 Hz. The unit comes complete with a penetration sensor which is monitored from the surface.

This apparatus can be used easily from a non-specialized vessel, provided it is equipped with hauling tackle. To date it has been used successfully around the coast of France, in Senegal, Nigeria, England, Scotland and Martinique. In 1975 off the coast of France (Southern Brittany), the equipment was used to take 284 m of core in 52 corings during a seven-day period. The soil was sand, gravels, and pebbles and average core recovery was 93 percent. The equipment has been used in seas of 3 to 4 metres.

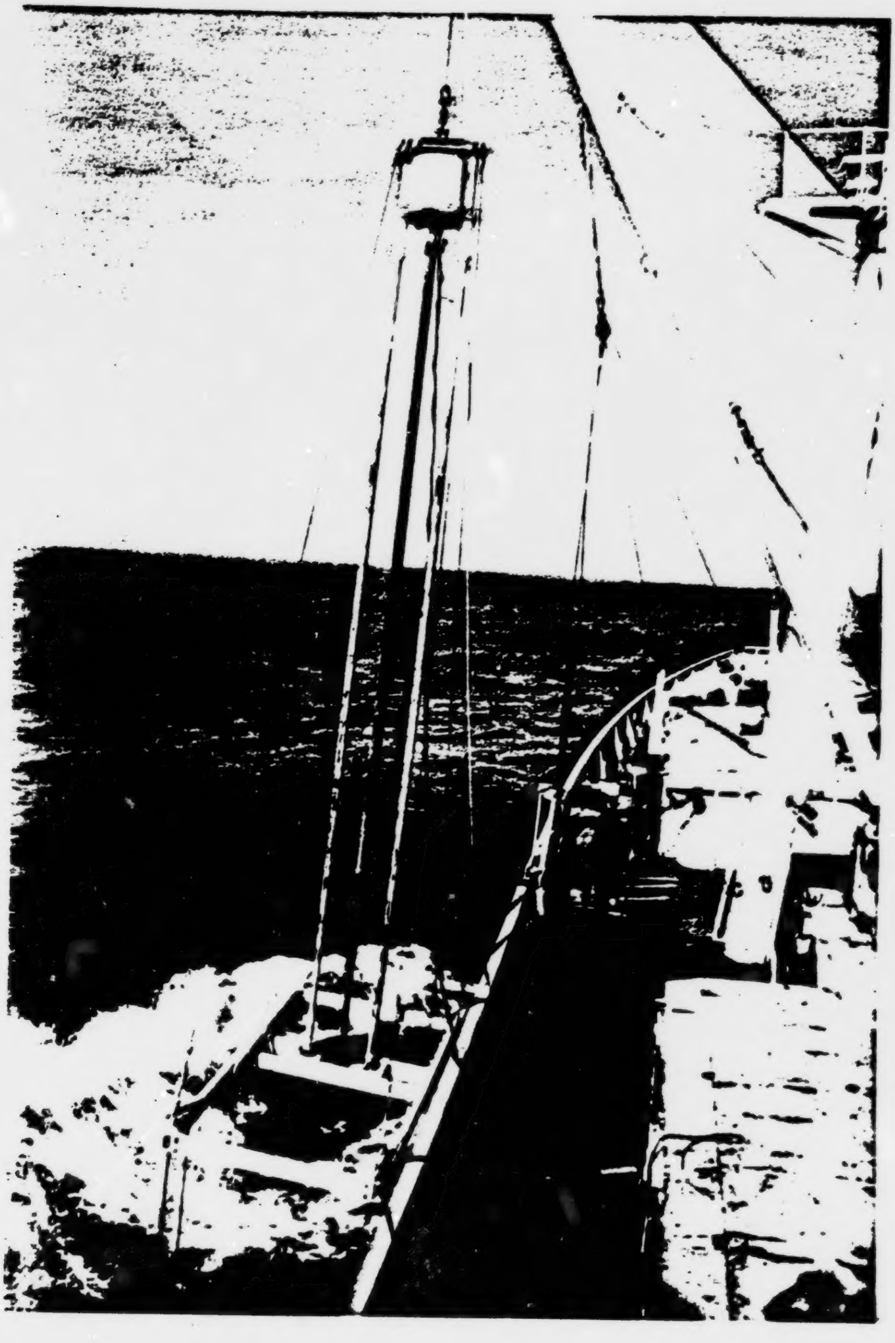


Figure 4.23 - Bureau de Recherches Geologiques et Minieres V.4.S.8 Vibrocoring Device

4.3.9 Rokleng Air Hammer (Figure 4.24)

Developed by Delft Soil Mechanics Laboratory, Holland. Manufactured by Seabed b.v., Ymuiden, Holland.

This system is capable of taking 100, 160, and 170 mm diameter cores in 5 m lengths from unconsolidated sediment. It has a depth capability of up to 100 m using special air hoses, and up to 60 m using standard equipment.

The Rokleng consists of a rectangular frame having two vertical pillars on which the main housing slides. One side of the frame is equipped with sea-current vanes and the entire unit is strengthened with wire braces. The unit is 5.0 m long, 1.11 m wide, 6.45 m high and weighs 900 kg in air.

The air hammer (as the name implies) is pneumatically driven from the support vessel with a compressor. Air consumption is 1.5 cu m/min at 6 bar. The complete system can be equipped with inclination indicator and an electric or air valve penetration sensor.

The manufacturer claims the main advantages of the equipment are its troublefree operation and high penetration rates.

The equipment does not have core barrel retraction equipment and relies on the support vessel to pull out core as the sampler is retrieved. This necessitates an onboard winch capacity of approximately 2,000 kg.

The equipment is not generally advertised by Seabed and is not presently favoured. A hydro hammer version is under development but is not yet complete (Seabed b.v. 1986).

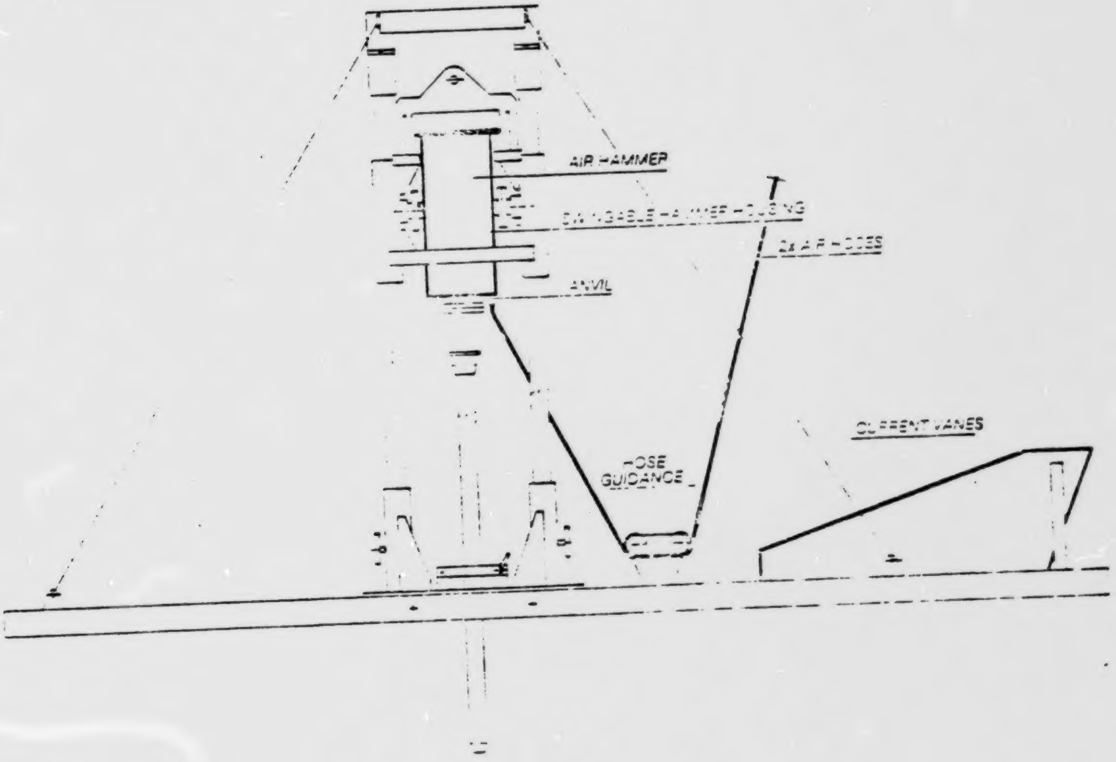

AIR HAMMER
SWINGABLE HAMMER HOUSING
2x AIR HOSES
ANVIL
HOSE GUIDANCE
CURRENT VANES

Figure 4.24

Rokleng Air Hammer

4.3.10 Seabed Vibro Corer (SVC 500E and SVC 500 ETR) (Figure 4.25)

Manufactured by Seabed b.v., Ymuiden, Holland.

These systems replace the Vibra-hammer (Duits "Senkowitch").

The systems are capable of taking up to 100 mm cores, 5 m long in up to 300 m of water. It has been designed for use in soft cohesive soils and weighs 750 kg in air (Seabed b.v., Undated).

The drive mechanism consists of two synchronized electric motors each 2.2 kw. Power is supplied by an umbilical at 380 V, 3 phase, 50 hertz. No core barrel retraction system is incorporated.

The unit is controlled from a containerized control display which includes a penetration slide indicator.

Although the two units perform virtually identically, the SVC 500 ETR has been designed to be mobilized quickly by virtue of its optional transport and assembly facilties. Fully assembled, it consists of a rectangular frame having two vertical pillars on which the vibro head slides. It stands 6.0 m long and 6.35 m high but when folded up is 2.6 m long by 1.65 m high. One end of the base frame is equipped with vanes to align the platform with the prevailing current direction.

The SVC 500E has basically the same configuration and its dimensions are 5 m long and 6.4 m high. The mast and vibrohead can be removed.

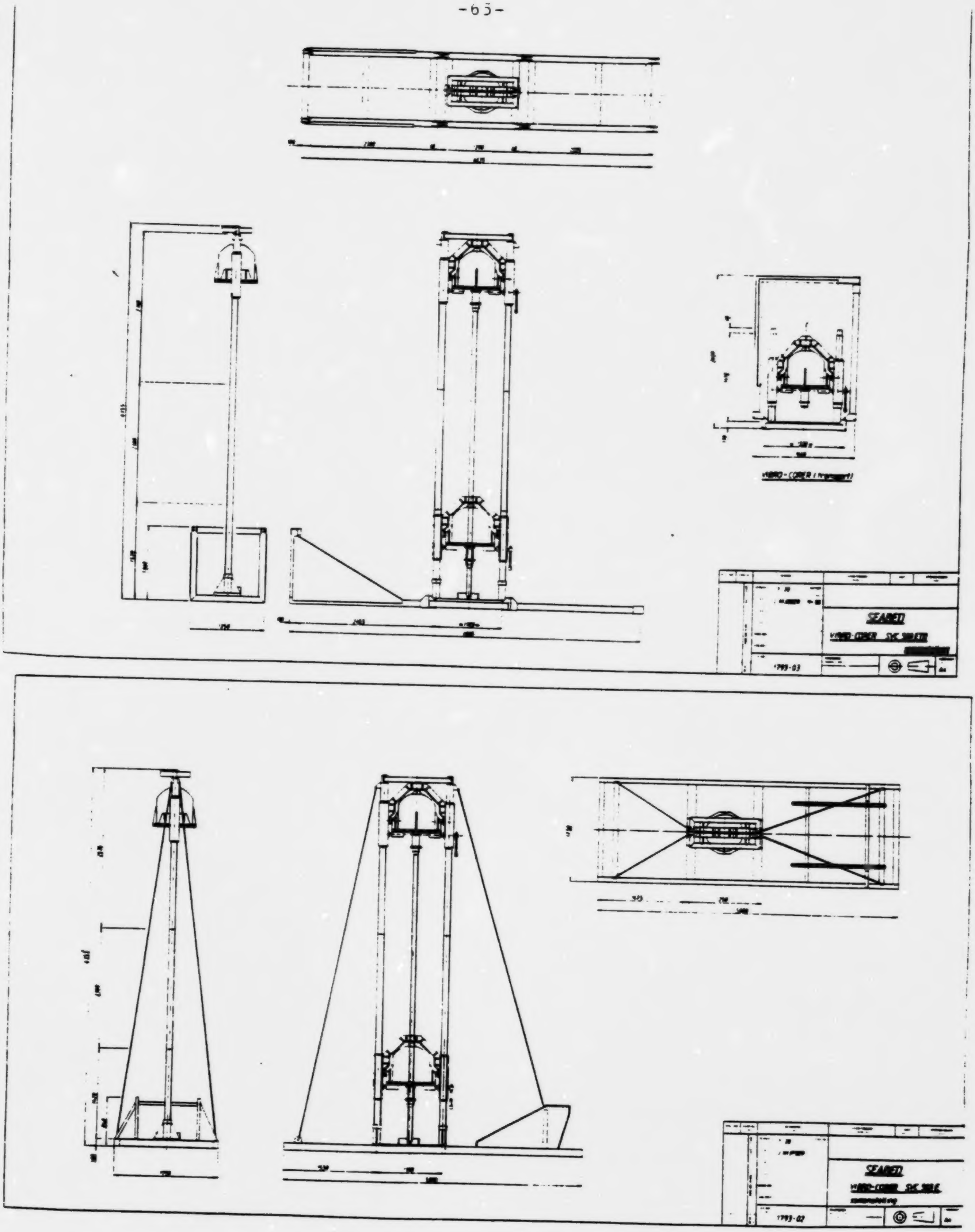

VIBRO-CORER (transport)
SEABED
VIBRO-CORER SVC 500 ETR
1793-03
SEABED
VIBRO-CORER SVC 500 E
1793-02

Figure 4.25

Seabed Vibrocorer SVC 500 E and SVC 500 ETR

4.3.11 Geomarex - P1, P4, P6, P10 Vibrocorers (Figure 4.26)

Developed by Geomarex of La Jolla, California.

The P1 vibrocorer is capable of taking 75 mm, 90 mm or 100 mm samples of unconsolidated sediments in 6 m lengths in water depths up to 500 m.

It is available for use in a rigid frame or buoyant frame. The rigid frame consists of two vertical pipes extending from a base plate, approximately 7 m long and intended for onshore use. The buoyant frame consists of a float package and a PVC base incorporating a weight chest. This frame is used for underwater applications and the float package vertically orients the core tube. The buoyant frame is approximately 0.74 m x 0.57 m x 7 m high. Total weight in air is 110 kg (Geomarex 1984/6).

The vibrohead comprises contrarotating eccentric vibrators electrically powered via an umbilical from the support vessel at 100 VAC, single phase, 1.5 kw. Water jetting and reverse circulation options are available.

The P4, P6 and P10 models use the same basic configuration but have different capabilities. The P4 model can take cores up to 100 mm in diameter and 6 m long but uses two vibraheads instead of one to achieve penetration more efficiently. It is powered by umbillical at 220 VAC, 3 phase, 3 kw and weighs 275 kg.

The P6 model can take cores up to 165 mm diameter and 6 m long by using larger vibroheads.

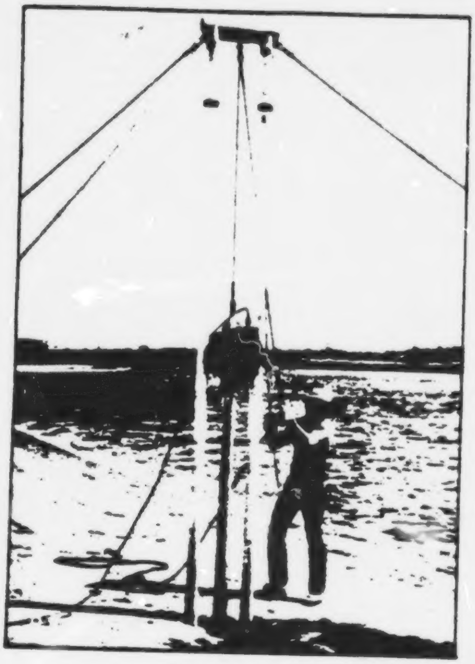
The P10 will take cores up to 250 mm dia, 6 m long but weighs significantly more than the smaller models.

All models rely on the support vessel hoisting winch to retrieve the core barrel.

The P4 system was used off the west coast of South Island, New Zealand (1982) for placer evaluation. Some difficulty was encountered in retrieving cores more than 3 m long owing to the very fine compacted nature of the sediments. This problem was alleviated by using thin wall aluminum corebarrels without liners (Geomarex 1986).

The following prices apply (Canadian dollars - 1985):

	P1	P4
Purchase cost	$23,000	$40,000
Equipment preparation	1,400	1,670
Equipment lease	350/day - 1st week 240/day thereafter	450/day 10% discount after 30 days 20% discount after 60 days
One operator	350/day	490/day



Model P1

Model P4

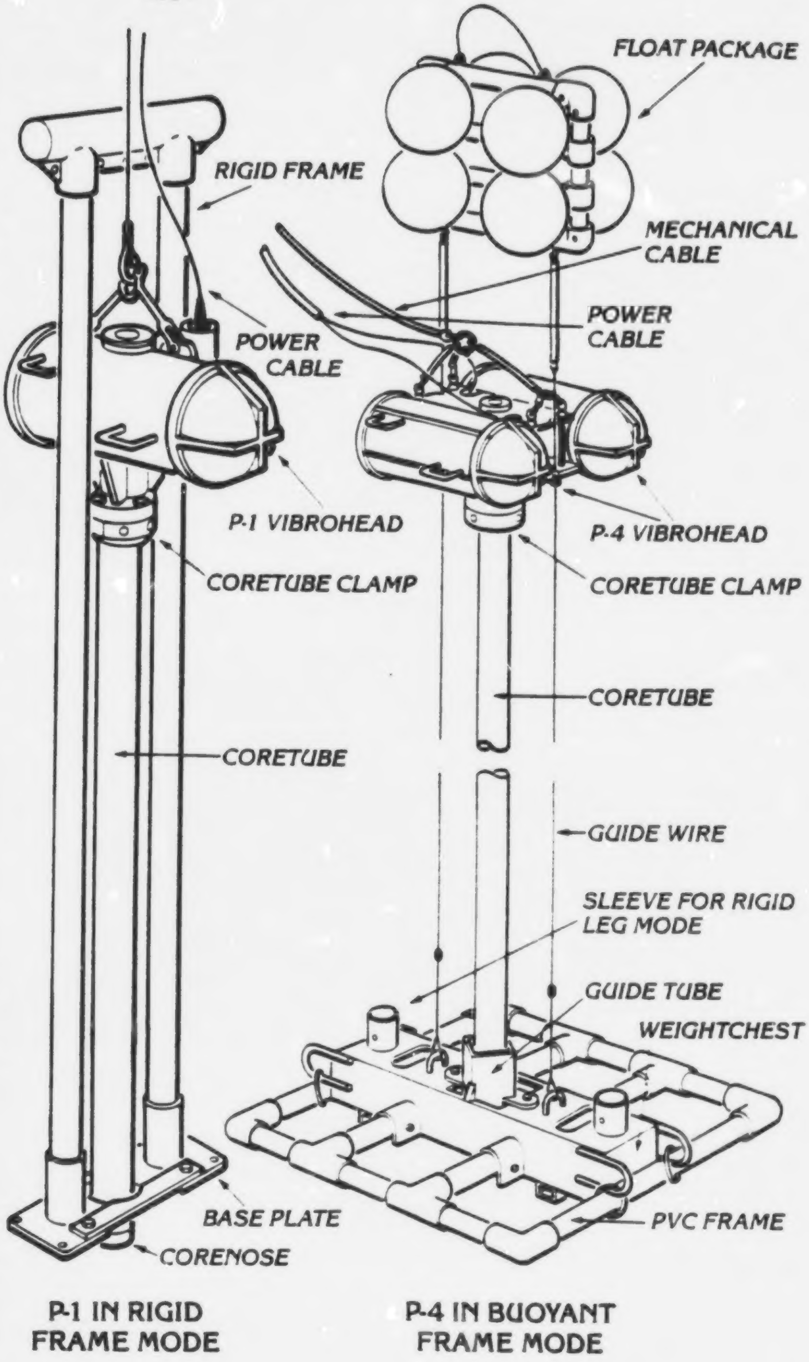

FLOAT PACKAGE
RIGID FRAME
MECHANICAL CABLE
POWER CABLE
POWER CABLE
P-1 VIBROHEAD
P-4 VIBROHEAD
CORETUBE CLAMP
CORETUBE CLAMP
CORETUBE
CORETUBE
GUIDE WIRE
SLEEVE FOR RIGID LEG MODE
GUIDE TUBE
WEIGHTCHEST
BASE PLATE
PVC FRAME
CORENOSE
P-1 IN RIGID FRAME MODE
P-4 IN BUOYANT FRAME MODE

Figure 4.26

Geomarex Vibrocorer

Model P1 and P4

4.3.12 Mackereth Portable Core Sampler (Figure 4.27)

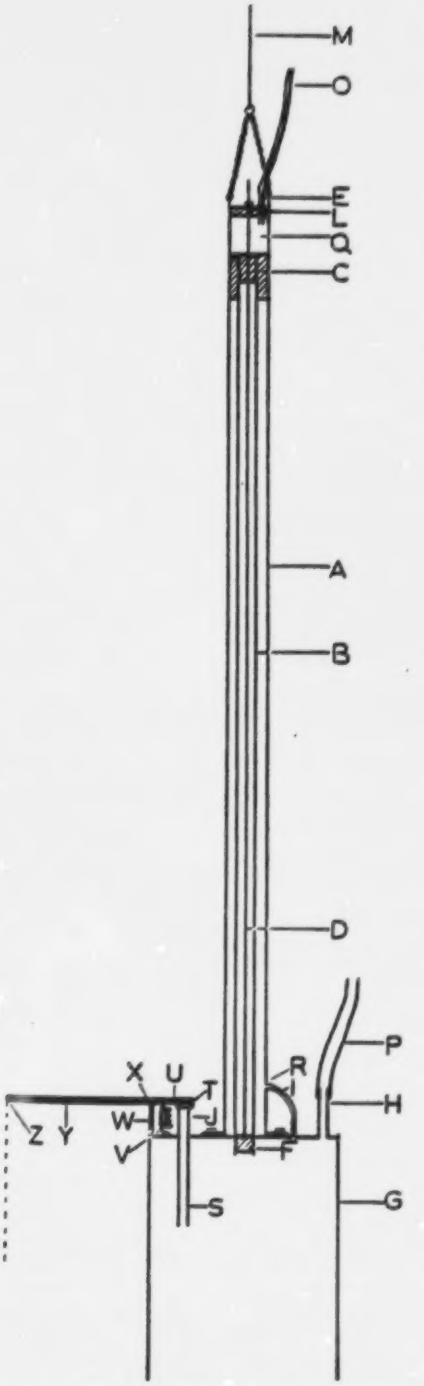
Developed by Freshwater Biological Association, The Ferry House, England, 1959 (Mackereth 1969).

This system is capable of taking 38 mm diameter cores 6 m long from sediment in water depths up to 250 m.

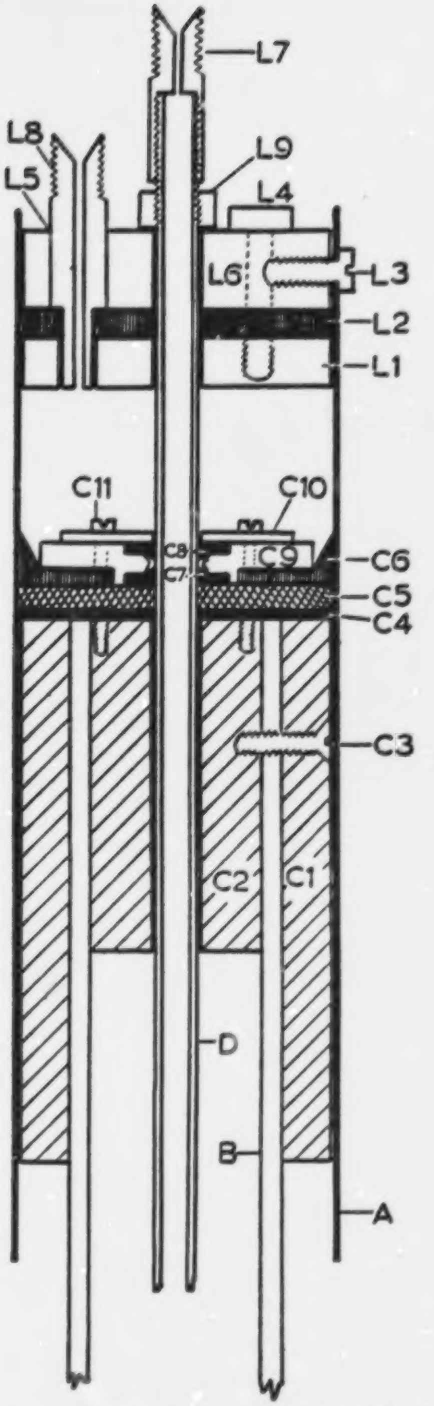
The unit is approximately 7.5 high and 0.5 m in diameter at the lower end. Hydrostatic pressure operating on a cylindrical anchor chamber embedded in the sediment is used to hold the apparatus in contact with the bottom. The core barrel is similar in design and utilizes a piston, like conventional gravity/piston corers.

However, unlike conventional gravity/piston corers, the Mackereth corer uses compressed air supplied from a surface generator to drive the core barrel into the sediment. On completion of coring, the anchor chamber is automatically filled with air, the coring tube is extracted from the sediment and the apparatus brought to the surface by the buoyancy lift.

This corer is easily portable and may be used by two men from a rowboat.


M
O
E
L
Q
C
A
B
D
P
R
H
X
U
T
W
J
Z
Y
V
F
S
G

Diagrammatic cross section of the complete apparatus, not to scale. Letters referred to in the text.


L7
L8
L9
L5
L4
L6
L3
L2
L1
C11
C10
C8
C9
C6
C7
C5
C4
C3
C2
C1
D
B
A

Details of the sealing components of the upper end of the apparatus and of the driving piston. Letters referred to in the text.

Figure 4.27

Mackereth Portable Core Sampler

4.3.13 Marex Vibrocorer (Figure 4.28)

The Marex Vibrocorer is capable of taking 63.5 mm diameter cores, 3.9 m long from from fine sand and clay. Much shorter cores are normally obtained from gravel (Kirby 1972).

The vibrocorer consists of a vertical tower 6.75 meters high when erected. The tower consists of upper and lower triangular steel plates with a 100 mm diameter x 6.5 meter long tube linking each of the triangular apexes. The system has a leg span of 4.5 metres and weighs 1.4 tonnes in air. The triangular section vertical tower is held in an upright position on the seabed by tripodal legs extending from the tower.

The core barrel is 5.6 m long with a 75 mm outside diameter, however only 3.9 m is effective in recovering core since the upper 1.7 m is used to bolt the barrel to the vibrator.

The complete system is powered from a 3 phase, 110 V, 50 Hz, 3 kVA surface generator. The vibrator consists of two, 3 1/2 hp electric motors rated at 110 V, 3 phase, 50 Hz.

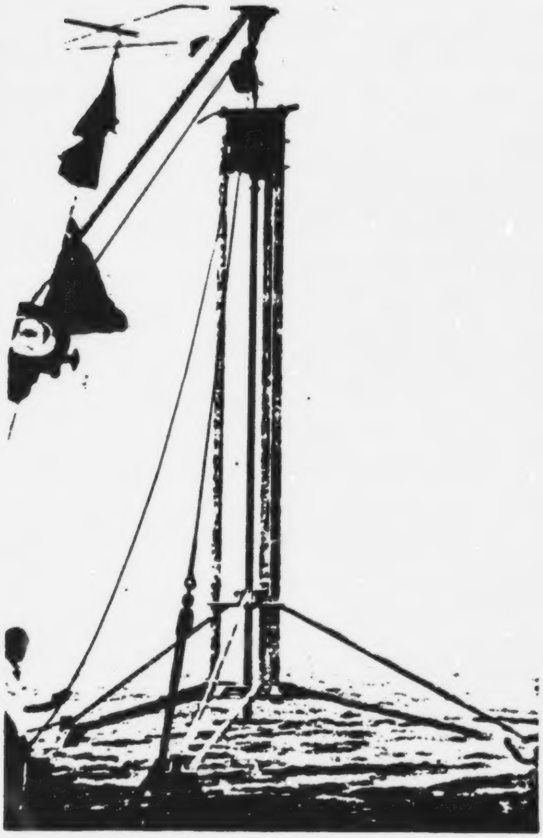


Figure 4.28 - Marex Vibrocorer

4.3.14 Haamer Vibrocorer (Figure 4.29)

Developed by Joel Haamer at the Institute of Geology, Chalmers College of Technology, Sweden, in conjunction with the Research Division of Dynapac Maskin AB. It is manufactured and marketed by Borros AB of Solna, Sweden, who now have an office in Toronto, Canada.

The system is capable of recovering 56 mm diameter cores 5.5 m long from unconsolidated sediments, gravels and clays in up to 80 m water depths.

The complete unit (without buoy) is 6 m long and weighs 480 kg in air (Borros AB, Undated).

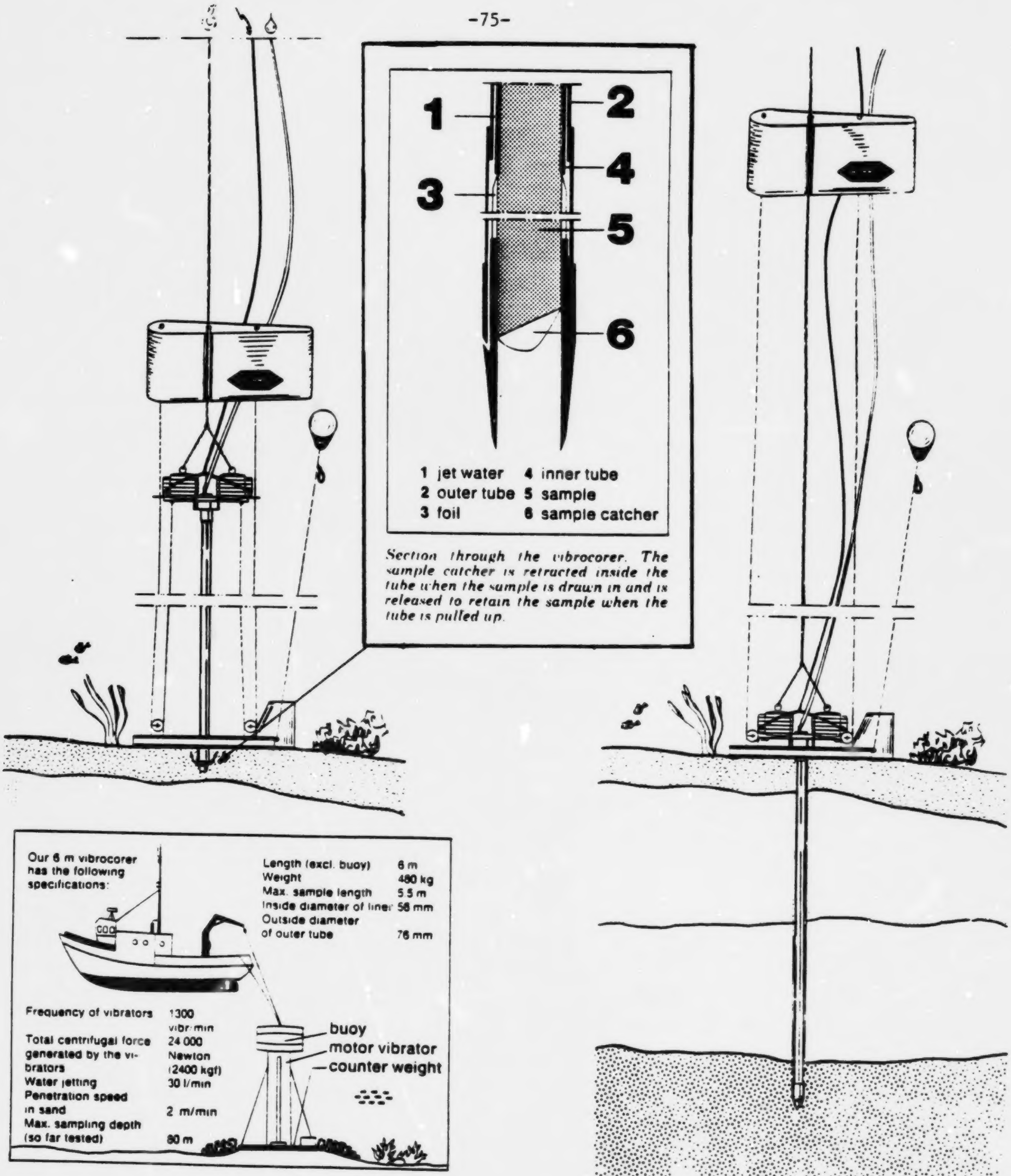
Penetration of the sampling barrel is actuated by two 380V, 2.9 kVA, 3 phase synchronized electrically driven vibrators - somewhat modified standard Dynapac equipment. Additional penetration force is provided by the buoyancy of a guiding buoy acting through pulleys in the base frame. A water jetting feature has been combined with the vibration. High pressure water is supplied from the support vessel at 40 bar, 40 l/min and is jetted out around the outer tube, near the cutter head, reducing the external wall friction. To extend the maximum sampling length and to decrease the degree of disturbance, the vibrocorer is equipped with a plastic foil, which encases the core as it enters the liner to reduce inside friction.

The equipment design parameters were very close to those of this project. The objective was to build sea bottom prospecting equipment from readily available standard components. It was to result in the construction of a vibrocorer which could be operated from an ordinary trawler or similar vessel without major modifiction. A 2 tonne crane is required to handle core barrel retraction and equipment placement.

The equipment was initially tested in Gothenburg Harbour, Sweden, and has since been used to drill over 300 holes. This has included sampling clay under a layer of gravel. The operating cycle is approximately 10 minutes and up to three samples per hour have been achieved (Jonasson 1976).

A 12 m version of this equipment has recently been manufactured. The core is 81 mm in diameter and 11 m long. The system weighs 1,000 kg in air.

A complete 6 m unit suitable for taking 56 mm diameter core can be purchased for approximately $47,000 Canadian (Borros AB 1986).


1
2
3
4
5
6
1 jet water
2 outer tube
3 foil
4 inner tube
5 sample
6 sample catcher
buoy
motor vibrator
counter weight

Section through the vibrocorer. The sample catcher is retracted inside the tube when the sample is drawn in and is released to retain the sample when the tube is pulled up.

Our 6 m vibrocorer has the following specifications:

Length (excl. buoy)	6 m
Weight	480 kg
Max. sample length	5.5 m
Inside diameter of liner	58 mm
Outside diameter of outer tube	76 mm
Frequency of vibrators	1300 vibr/min
Total centrifugal force generated by the vibrators	24 000 Newton (2400 kgf)
Water jetting	30 l/min
Penetration speed in sand	2 m/min
Max. sampling depth (so far tested)	80 m

Figure 4.29

Haamer Vibrocorer

4.3.15 Alluvial Mining Vibrocorer (Figures 4.30 and 4.31)

Developed by the Alluvial Mining Co., U.K.

This vibrocorer is capable of taking 85 mm, 100 mm, and 150 mm diameter cores in 4 m, 6 m, 8 m, and 10 m lengths. It is generally rated for 100 m water depth and weighs 1.85 tonnes and 2.15 tonnes respectively for the 4 m and 6 m models (Alluvial Mining, Undated).

The unit is driven by twin linear electric vibrator motors, each 3 hp, 440 V, 3 phase, powered via an umbilical from the support vessel. Control functions include voltmeters, ampmeters and an acoustically linked penetration recorder. Additional penetration ability is available by using a water jetting core barrel to reduce external wall friction. A core barrel retract winch is provided.

The unit consists of a tripod frame supporting three vertical members. Height and width range from 4.1 m high and 3.7 m wide for the 3 m version to 7.8 m high and 6 m wide for the 6 m version.

The unit is very similar to the BGS (IGS) Aimers-McLean vibrocorer which was probably used as the design basis for the Alluvial Mining vibrocorers.

The 3 m or 4 m vibrocorer has been used from a 50 foot fishing vessel and Alluvial Mining believe that a 6 m or 8 m version could be operated from a 200 tonne, 30 m fishing vessel.

Alluvial Mining stated that their equipment could sample a wide range of soils including unconsolidated gravels with stones 38 - 50 mm in diameter. As well, most of Alluvial Mining's crew are ex-fishermen who have worked with J. Marr and Sons who carry out coring surveys to utilize vessels in between fishing trips (Alluvial Mining 1986).

The equipment was used in the spring of 1979 off the Eastern U.K. Coast in 6-10 m water depths from an eighty foot trawler. Sixty-five core stations were sampled in 7 days with the 3 m system in sands, gravels, silts and clays (Alluvial Mining, Undated).

In the winter of 1978/79, it was used from a trawler in the Irish Sea with the 4 m version in 30 m water depths. A total of 74 stations consisting of sands, silts and gravels were sampled in 20 days. The trawlers used a 1, 2, or 3 point mooring system and had two 4 tonne derricks with a 4 barrel winch (Alluvial Mining, Undated).

The vibrocorer package can be rented for $525/day excluding consumables and personnel or it can be purchased new for $63,000, or used for $38,000 (Canadian dollars - 1985) (Alluvial Mining, 1986).

Recent developments of the vibrocorer have included addition of a vibro-impact feature (see Figure 4.31). The characteristics of the sampling material causing resistance to penetration and recovery are overcome by the application of both vibration and impact forces. It is housed in the same frame as the vibrocorer and is available in either pneumatic, hydraulic or electric powered versions. The vibra impact corer is available in 3 m, 4 m and 6 m core lengths and the pneumatic version ranges in weight up to 2.2 tonnes while the hydraulic version ranges up to 3.6 tonnes. The electric version ranges up to 2.15 tonnes (Rodger et al 1986).

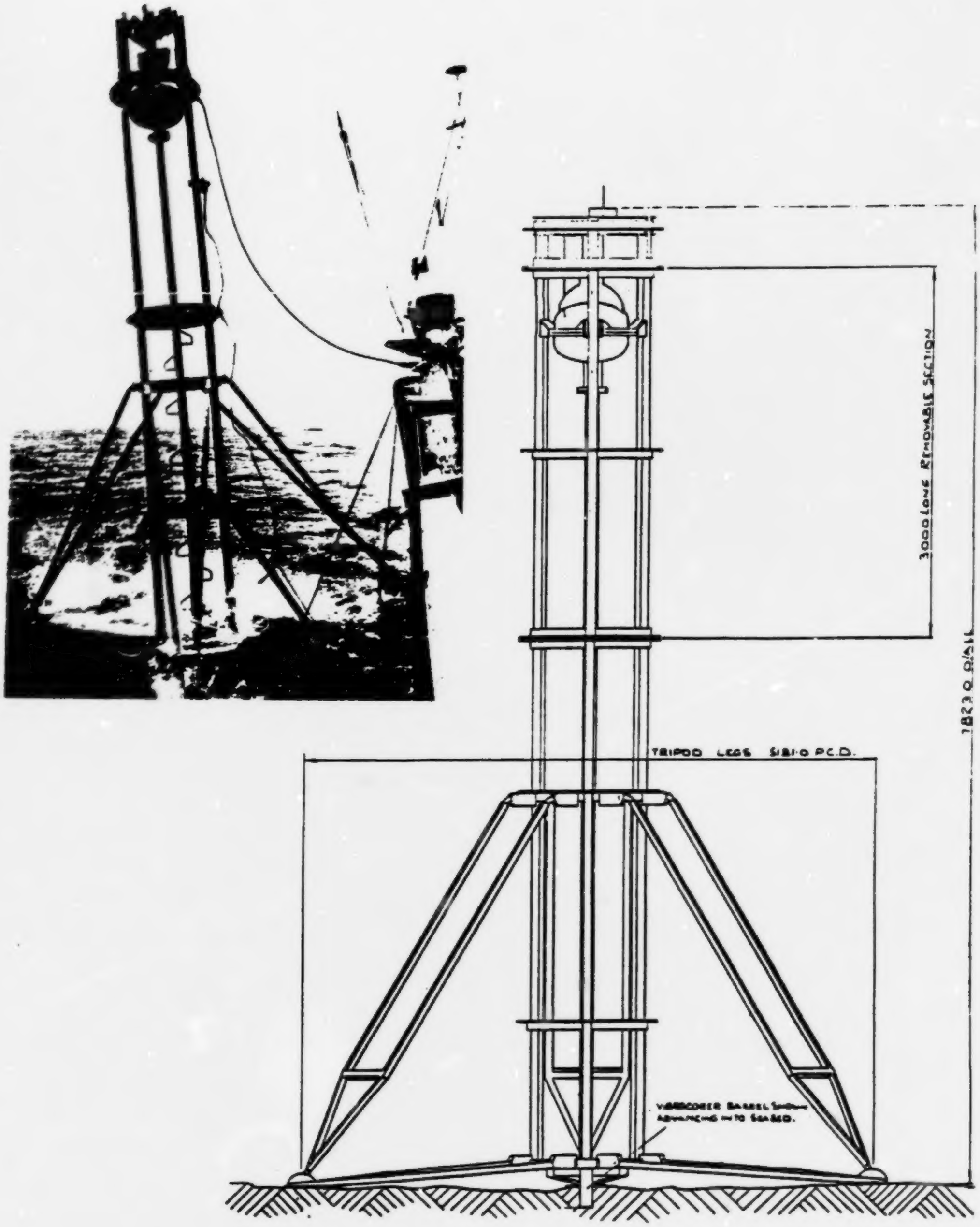
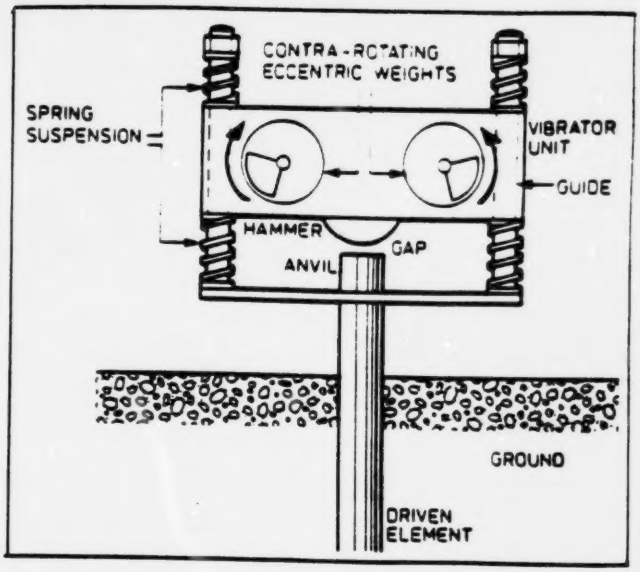

3000 LONG REMOVABLE SECTION
1823.0 O/ALL
TRIPOD LEGS 5181.0 P.C.D.
VIBROCORER BARREL SHOWN ADVANCING INTO SEABED.

FIGURE 4.30 Alluvial Mining Vibrocorer


CONTRA-ROTATING ECCENTRIC WEIGHTS
SPRING SUSPENSION
VIBRATOR UNIT
GUIDE
HAMMER
GAP
ANVIL
GROUND
DRIVEN ELEMENT

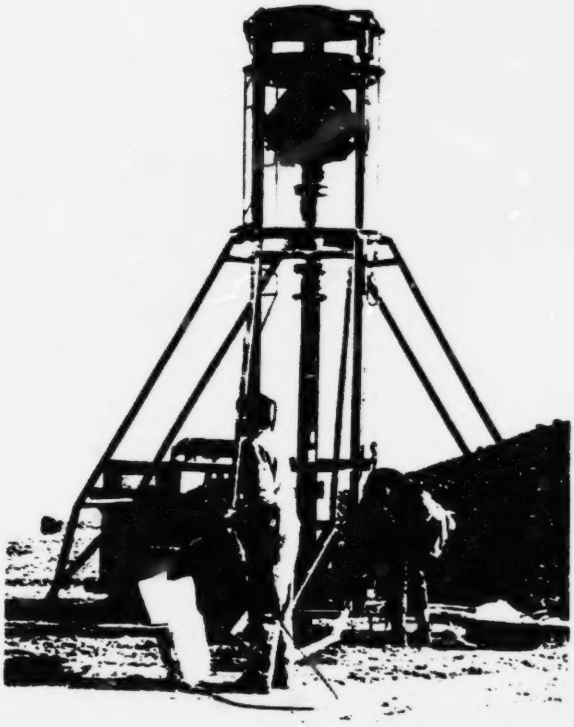


FIGURE 4.31 Alluvial Mining Vibro-Impact Corer (VIC) Mechanism

4.3.16 Alpine Vibracore (Figure 4.32)

Developed by Alpine Ocean Seismic Survey Inc. 1964 (previously Alpine Geophysical Associates Inc.) (Meisburger and Williams 1981, Tirey 1972, Alpine 1986).

The Alpine Vibracore is capable of taking 89 mm diameter cores, 12 m long, from sediment consisting of stiff clays, sands, and gravels in water depths up to 300 m. Less success has been encountered while coring glacial tills and gravels with little or no sand.

The standard system consists of a 14.1 m high aluminum or steel "H" beam supported by 4 legs, weighing 1,800 kg in air. Shorter versions for taking 6 m and 9 m long cores are also available.

The Vibracore utilizes a pneumatic impacting piston vibrator operating on 250 cu ft per minute at 120 psi.

An air compressor aboard the surface support vessel provides the requisite driving air by means of a single wire-reinforced hose. Two additional hoses of the same type are used to return the exhaust air to the surface so that it is not necessary to exhaust against the ambient hydrostatic pressure.

A pulley arrangement allows the hoisting line to pull out the core before lifting the unit from the seafloor. Although the unit weighs approximately 2 tonnes the pullout load is on average 10 tonnes and can be as high as 30 tonnes.

The system has been used successfully for over 18 years by the U.S. Army Corps of Engineers to obtain over 1,600 cores on most U.S. inner continental shelf areas.

Operation usually required one skilled operator and two semi-skilled helpers.

The unit is presently being operated from an 80 foot twin hulled purpose built vessel owned by Alpine - the R/V Atlantic Twin.

Equipment is available for use at the following rates (Canadian dollars - 1986):

Vibracore	$490/day
R/V Atlantic Twin	$2,220/day
2 man vibracoring team	$833/day

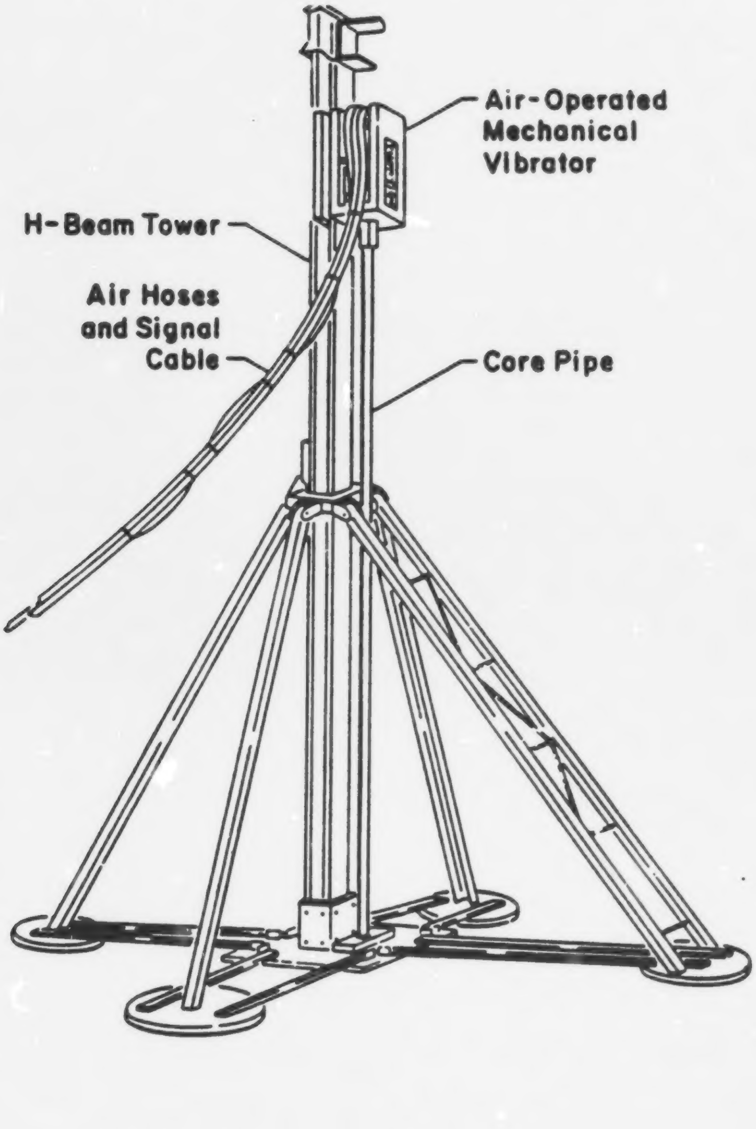

Air-Operated Mechanical Vibrator
H-Beam Tower
Air Hoses and Signal Cable
Core Pipe

Figure 4.32Alpine Vibracore

4.3.17 Wink Vibra Core (Figure 4.33)

Developed by Mr. Fred Wink in 1980. It is now marketed by Sonic Soil Sampling Inc. in Toronto, Ontario, and also by VI-COR Technology Inc., of Vancouver, B.C. (Sonic 1986, Vi-Cor 1986).

The unit uses a vibratory head similar to that used in concrete vibrators. It is powered by a drive cable up to 4.5 metres long from an 8 hp Honda motor. The complete system, without drill rods, weighs 36 kg. Standard sized drill rods are used ranging from AQ with 35 mm I.D. weighing 6 kg/m to NQ with 60 mm I.D. weighing 9.1 kg/m.

The system was designed for land use and has been successfully used in Timmins and Red Lake, Ontario and Suriname, South America.

The equipment has been adapted for use in nearshore areas of the Nova Scotia Shelf. In September of 1985 Mer Resources used a 12 metre fishing vessel, the Golden Dome, to sample placer deposits. A 3 tonne hydraulic forklift system was mounted on the stern of the vessel with a platform in place of the forks. The forklift system was used to support the drill rods and retrieve them once coring was complete. A total of 154 holes were completed with depths up to 6.7 metres in sand and sediments. Very little gravelly materials was encountered. Once drilling commenced an average of 2 minutes was required for full penetration. A three-point mooring system was required and operations could not be carried out in waves heights greater than 1 metre.

Equipment rental rates are $250/day or 7,500/month. With 2 operators, equipment rental rates are $600/day and $15,000/month (Sonic 1986).

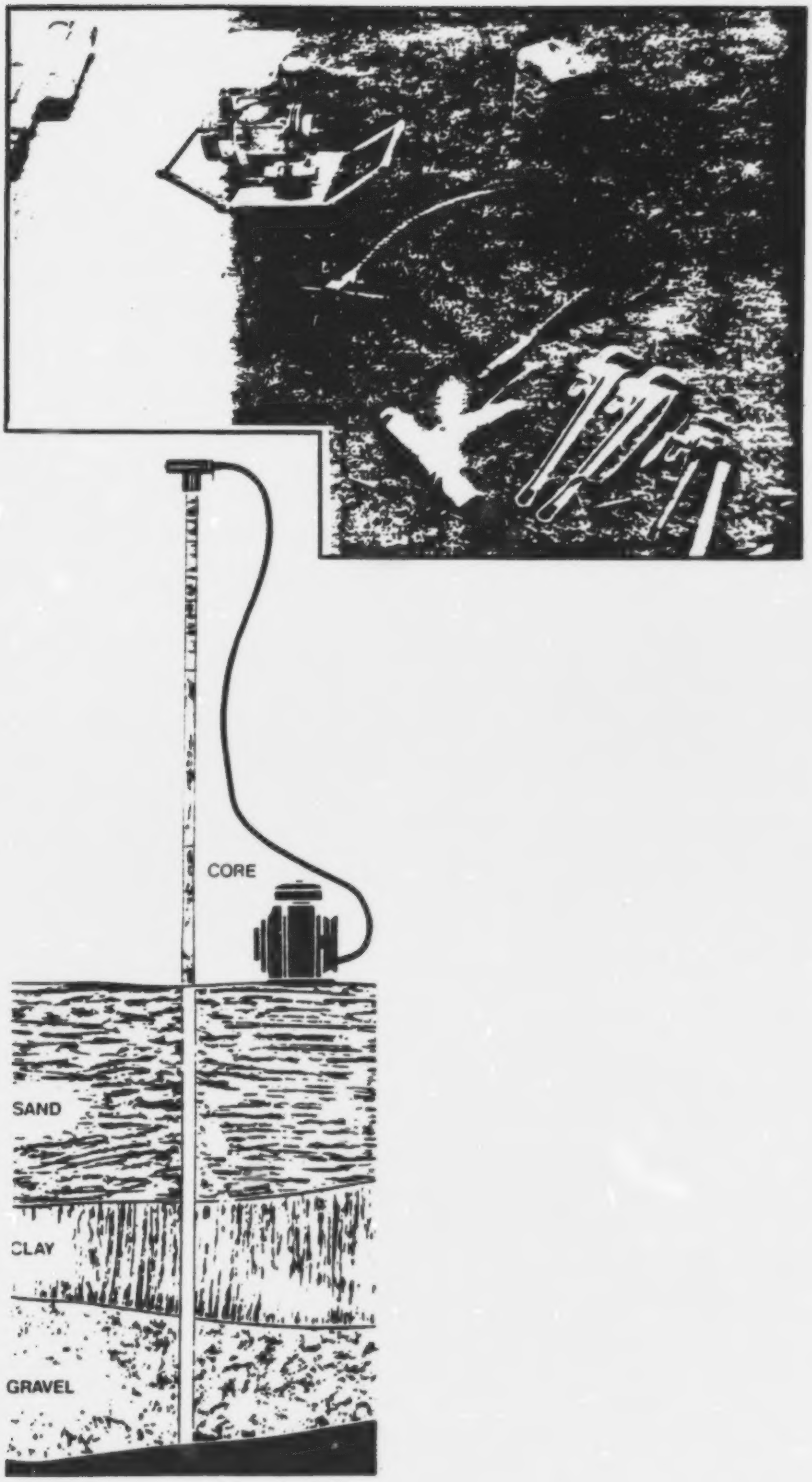

CORE
SAND
CLAY
GRAVEL

Figure 4.33

Wink Vibra Core

4.3.18 Horton Vibrocorer

Designed by Ocean Science and Engineering and manufactured by them before they went out of business earlier this year.

It is capable of taking a 30 m, 152 mm diameter sample of unconsolidated sediment, gravel or sand in water depths of up to 60 m.

The system consists of an hydraulically powered vibratory unit mounted on the side of the drill pipe and above water. The vibratory unit is moved up the pipe as the pipe penetrates the seabed. Pipe is added in 3.1 m lengths.

The unit required the use of an "over the side" mounted derrick on the support vessel. The derrick is used to support the pipe laterally and to provide lifting capabilities for core barrel retrieval. Use of the vibrator head is often necessary to retrieve the core.

The equipment is relatively insensitive to vessel heave because the vibrator head is fastened directly to the core pipe and the core pipe is free to move vertically, relative to the derrick. Lateral motion must be kept to a minimum and generally requires a four-point mooring system.

Ocean Science and Engineering and the Anglo American Group used this equipment in 1966 to conduct a heavy mineral exploration program off the coast of Tasmania from the 30 m vessel R/V Wanda River. During the five-month program 171 sediment samples were taken to an average subseabed depth of 7.6 m (maximum of 27 m); water depths averaged 28 m. Approximately 27 percent of the potential drilling time was lost due to adverse sea states (Dimock 1986).

Some sample was lost due to the combined effect of an inadequate core catcher and the need to use the vibrator to retrieve the core barrel.

4.3.19 Geomarex Hummingdrill Vibrocorer

Developed in 1983 and manufactured by Geomarex at La Jolla, California.

The unit is a portable vibrocorer capable of 3.7 m to 5.5 m cores up to 89 mm in diameter and weighs 11.4 kg. It was designed for overland prospecting in unconsolidated and/or water logged sediments.

The vibratory head is a dual eccentric "vibrosinker" powered via a flexible cable shaft by a 5 hp gasoline engine. Water jetting can be implemented if desired for increased penetration (Geomarex 1983).

The unit comes with a stand which provides pulldown or lifting of the core barrel.

It is very similar in function to the Wink Vibra Core (Section 4.3.17).

If used offshore, the unit would have to be modified or used with the vibratory head above water as it was not designed to be submerged. It has not been used in this manner to date.

4.3.20 Dutch Geological Survey - Roflush II

Developed by the Dutch Geological Survey in 1986.

The unit consists of a 1 tonne, frame-mounted, air hammer to drive a double walled core barrel, I.D. 90 mm. A counter flush system is incorporated to continuously bring samples to the surface.

The unit is still under development but was scheduled to go for sea trials in April/May 1986 (Seacore 1986).

4.4 SEABED MOUNTED ROTARY CORERS

In the early 1960's bottom mounted rotary drills were developed in order to recover samples from hard formations in deep water. Small rock core drills were developed for geological mapping purposes by organizations such as the Bedford Institute of Oceanography. Rock cores 25 mm in diameter and up to 5 meters long have been obtained from bottom mounted, surface controlled, electric rock core drills. Larger core diameters are preferred for geotechnical testing but bedrock samples of greater diameter than this may be difficult to break off once the drilling is complete.

In these systems a submersible electric motor is normally used to rotate the core barrel. Penetration of the core barrel is normally aided by the provision of downward thrust which is limited by the submerged weight of the system.

In some units additional downthrust force has been developed by using pressurized sea-water or hydraulic fluid units placed on top of the core barrel. As with many vibrocorers, a core barrel retraction capability is desirable to minimize the possibility of bending of the core barrel as it is pulled from the hole.

The sorting mechanisms involved in the formation of placer deposits indicate that there may be a relatively high concentration of gold at the soil/bedrock interface. It may be necessary to sample the top of the bedrock to determine the presence of gold at the interface, and this may require sampling through substantial overburden thicknesses.

Remotely operated rotary corers have proved effective in recovering cores from exposed unfractured bedrock. Fractured rock pieces, however, often cause the core barrel to jam and overlying sediment containing stones can also cause plugging of the core barrel. Operational experience with some rotary corers indicates that the requirement to use a flushing medium to lubricate the bit and remove cuttings, may cause problems in attempts to core sediments since fine grained material may be washed away by the flushing medium. Recent modifications and/or new developments such as the use of drilling mud as a flushing medium may have gone at least part way towards solving this problem.

The following seabed mounted rotary corers were considered for this study. Additional details of these systems are given in Table 4.3. Addresses of selected equipment manufacturers are given in Appendix A.

TABLE 4.3 ROTARY CORERS

	SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
1.	Naval Engr. Lab Remote Controlled Seafloor Incremental Corer	Sediment and Bedrock	1800 m	15m / 76mm in 1.52 m long increments	7000 kg.	5.0 m/ 4.0 m	Fully remote controlled. TV camera is includ. and command, transmission & response is via FM	75 KVA at 440V/60Hz, 3 PH and 110V/60 Hz, single phase	Yes	Revolving turret drill pipe holders and a high degree of automation make it an expensive system. Unit failed most tests and is abandoned.
2.	Geodoff II	Sediment and Bedrock	200 m	48m / 150mm in twelve 4m long increments	4800 kg.	10 m/ 6.6 m	Penetration rate, probably others but no indication is given. Has onboard computer.	Unknown	Yes	System has 12, 4m long core barrels on a rotating disc. Recently converted to 10,000 counterflush system to sample to 30m in 1.5m increments being used in Australia for Placer exploration.
3.	Koken Drill	Bedrock	150 m	24m / 48mm	Unknown	27 m/ 5.0 m	Drill water press, drill feed rate and length, hydraulic circuit pressure	Unknown	Unknown	Large system - Difficult to handle.
4.	French Petroleum Institute ECSM2	Bedrock	300 m	1m / 90mm	Unknown	7.0 m/ 5.5 m	Inclinometer, depth of bit below seabed, drill wgt. and speed surface controls for drill weight/ speed, drill water pump and core sampler	100 KVA at 380V/ 50 Hz, 3 PH	Yes	Drill pipe is flexible with a rigid core barrel and diamond bit at the end. This allows downhole samples to be taken.

TABLE 4.3 CONTINUED

	SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
5.	Lockheed Corer Rotary	Bedrock	100 m	2.6m / 51mm	500 kg	4.6 m/ 2.8 m	Power consumption and core barrel penetration	4 hp at 208V/60 Hz 3 ph via a separate umbilical. (3 hp drill motor, 1 hp flushing water motor)	Yes	Can be handled from the deck of most vessels having a one-ton crane.
6.	C-Core Geotech Corer	All types of soil from bedrock to loose sand and gravel	100 m	5m / 64 mm	2000 kg.	5.5 m/ 2.6 m	Motor current, tilt, flushing pressure and penetration measured	15 hp drill motor	Yes	Original design modified to retain more fine grained sediments by using drill mud.
7.	Geological Survey of Japan "MD-300PT"	Rock outcrops covered by thin sediments Bedrock	300 m	0.75m/36mm	1070 kg.	2.3 m/ 2.0 m	Fully automatic; no instrumentation	Battery powered. 48 VDC. Power requirements unknown.	Yes	It was successfully operated in 1.5 knot currents near Tokyo
8.	Woods Hole Rock Drill	Bedrock	4000 m.	1m / 19mm after penetrating thru up to 1m of sediment	860 kg.	2.9 m/ 2.9 m	Unknown	3.7 kw at 36 VDC supplied by three automotive 12 VDC batteries in series for 24 min. of drilling	Yes	
9.	NORDCO Electric Rock Core Drill	Bedrock	2000 m	5.75m/25mm 9.14m version also available	1000 kg.	6.1 m/ 2.0 m	Drill tilt, flushing press., motor current, core barrel extension	3.7 kw at 3 ph 460 VAC or 575 VAC	Yes	Bit does not retain sediment other than rock core. Used successfully in Eastern Canada, Norway, & Australia. Problems in coring through fractured rock.

TABLE 4.3 CONTINUED

	SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
10.	Texas A & M Seacore 50 Automatic Marine Corer	Soft marine mud, sand, hard rock	300 m	15m / 76mm	4600 kg.	3.7 m/ 1.8 m	Highly instrumented; automatic operation	7.5 kw - Unknown voltage supply. Power supplied via a combined power/tension cable	Yes	Fully automatic controls make system expensive. Redundant manual controls are available for use from the ship. System never built
11.	Hyco Slack Line Corer	Bedrock	200 m	3.0m / 41mm	920 kg.	4.5 m/ 1.0 m	Tilt indicator, tachometer, drill feed rate, salt water leak detector.	7.5 kw at 440V/60Hz, 3 ph via a combined electro-load umbilical.	Yes	Was used successfully in Hudson's Bay from a 27.5m support vessel.
12.	Terrasearch Seabed Sampler	Consolidated & unconsolidated soils	300 m	10m / ?	10,000kg	11.0 m/ 4.5 m	Automatic drilling sequence. Solenoid activation monitored from the surface	Hydraulically powered from support vessel. 110 hp at 280 bar	Yes	Penetrometer readings can be taken at 1m intervals to the full 10m core depth
13.	Atlas Copco and Wimpey MARICOR	Clay, pebbles and rock	200 m	2.2m / 57mm 50m below seabed	14000 kg.	Approximately 6m / 3m	Highly Automatic	Electrical power is provided via single umbilical at 50 hp	Wire line recovery techniques for retrieving core are used. Retraction of drill string unknown.	Successfully used in several soil types in Scotland. Can adjust for seabed slopes up to 15°.
14.	Harrison Hard Rock Corer	Bedrock	150 m	0.25m / 10mm	160 kg.	1m / 1m	TV Camera. Command to drill is from surface operator.	Two 6VDC lead-acid batteries.	Unknown	Small size and weight allow unit to be used on small inshore boats.

TABLE 4.3 CONTINUED

	SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
15.	Conrad-Stork Drills	Clay, sand, sediment, gravel, consolidated and unconsolidated	Depends on drill type	50m /152mm continuous sampling (counter flush)	Depends on drill type and drilling depth.	Reverse circulation system uses 7m high A frame.	Monitoring of flushing water flow and pressure on reverse circulation system.	1. Original drill manually operated. 2. Other sytems require hydraulic pumps, with control panel and hoses, high pressure water pump & hoses. Winch and cable 7m high A frame	Casing is retrieved manually or by winch & cable depending on drill type.	1. Not a seabed mounted system. 2. Original drill hand powered and operated. 3. Cable tool percussion rig with hydraulic rotary table now available. 4. Reverse circulation(counter-flush) rotary drill also available.This requires 7m high A-frame on surface vessel
16.	Underwater Frame BSM12	Wide range of soils	100 m	12m / 115mm	4050 to 5000kg.	3.65m/5.7m without drill pipe and stabilizers extended.	All relevant functions including TV monitor.	48 kw to surface hydraulic power pack	Yes	Uses vibrohammer (with rotary drilling?) Available information is sparse.
17.	Mobile Auger and Research Ltd. DGD-2000	Wide range of soils and bedrock	600 m	600m in 1.5m/75mm increments	26000kg	Requires a shipboard derrick	Direct drilled from support vessel.	Self generated	No	Uses clump weight heave compensating system. Requires $63m^2$ of deck space Uses wireline techniques for drilling and sampling.
18.	SEASAM (Seabed Sampler)	Bedrock and sediment	200 m	6m / 100mm	5600kg.	9m / 3m	Penetration depth and speed, rotation speed, water depth. Can be continuously recorded on strip chart.	25 kw electrohydraulic. Hydraulic unit on sampler	Yes	System is portable. Cone penetrometer option available. Used successfully in Egypt and Libya.

TABLE 4.3 CONTINUED

	SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
19.	NORDCO Auger Drill (SEA-DRILL II)	Bedrock and sediment	2000 m	6.0m / 60mm sediment 6.0m / 25mm rock 4.5m or 3.0m versions available.	2000 kg. 6m versio	7m / 3m	Flushing pressure, core barrel extension, 2 axis of tilt, core barrel/drive tube/stub axle rotation, motor currents, compass, moisture alarms, buss voltage, plate positions, motor controller, and clutch engagement.	15 hp rotary drive and two 1.5 hp motors (auger and sampler plate) all at 460 V 60 Hz, 3 phase	Yes	System can auger through up to 6m of overburden and then take 6m rock core. Was successfully used in Bedford Basin and on Canadian East Coast Continental Shelf

4.4.1 Remote Controlled Seafloor Incremental Corer (Figure 4.34)

Developed by the Naval Civil Engineering Laboratory and Ocean Science and Engineering Inc., 1971 (Hironaka and Green 1971).

This system is capable of recovering 10 lengths of 1.52 m long cores, 76 mm in diameter from sediment or bedrock in water depths up to 1800 m.

The unit consists of a 5.0 m high frame, 3.0 m wide and 4.0 m long. With bearing pads extended (on seafloor) the unit is 7.0 m wide and 8.0 m long. It has a weight in air of approximately 7,000 kg.

The drill head, which incorporates a water swivel, is a specially designed unit for the corer. It is oil filled and ambient pressure compensated. Vertical movement of the drill head is accomplished by a hydraulic cylinder. The alignment of the drill head is maintained by rollers and a track attached to the derrick. The drill head is powered by a double hydraulic motor and is capable of two-speed operation, which is achieved by a series - parallel hydraulic circuit.

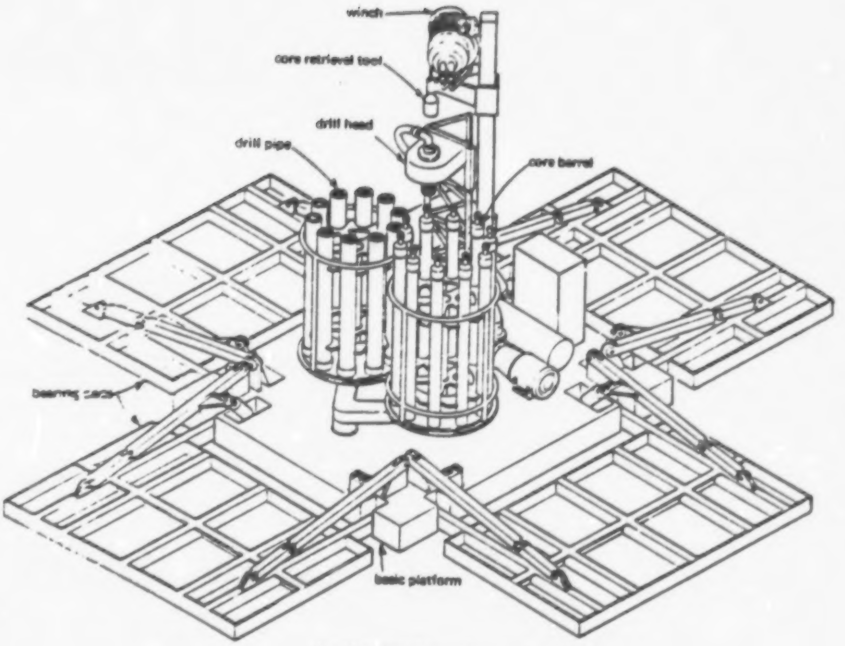
The drill pipes and core barrels are securely held in revolving turret-type holders. The turrets are held on a common base and moved over and away from the hole by means of hydraulic cylinders. Each turret is revolved independently to present to the work area either a pipe, a core barrel, or a place for storing as needed.

Electrical power (75 kVA, 440V/60HZ, 3 phase and 110V, single phase) is required to operate the corer. This power is transmitted via an electro-mechanical cable at 2,300 volts to the corer, where a transformer reduces it to 440 V, 3 phase and 110 V, single phase for use by the various components. The 440 V, 3 phase power is used to drive the 10 and 15 hp seawater pump motors and the 30 hp hydraulic pump motor. The 110 V, single phase power is used by all other components, including the FM transmitter and receiver units, relay coils, solenoids, and TV camera.

The unit was built, delivered and failed most tests. It has since been abandoned (Richards 1986).

Table 1. Seafloor Corer Specifications

Width (pads extended)	23 feet
Length (pads extended)	26 feet
Height (over winch post)	16 feet
Width (pads retracted)	10 feet
Length (pads retracted)	13 feet
Approximate weight in air	20,020 pounds
Approximate weight in water	15,640 pounds
Core barrel retrieval winch lift capacity	12,000 pounds
Drilling torque:	
high speed	2,000 ft-lbs at 100 rpm
low speed	6,000 ft-lbs at 30 rpm
Penetration profile capability	50 feet
Depth limitation	5,000 feet
Core diameter	3 inches
Core length (individual sample)	60 inches
Total number of sequential samples	10
Pump type, low pressure seawater	centrifugal
Size	1-1/2 x 3 x 9
Motor	15 hp at 3,600 rpm
Capacity	100 gpm at 200 ft head
Pump type, high pressure seawater	piston
Motor	10 hp at 1,200 rpm
Pump speed	1,200 rpm
Pump delivery	10 gpm at 1,000 psi
Hydraulic system, ambient pressure compensated	
Pump—gear type, double	1- and 2-inch wide gears
Pump drive motor	30 hp at 1,800 rpm
Volume/pressure	20 gpm at 2,000 psi 40 gpm at 1,000 psi



Assembly view of remotely controlled seafloor corer.

Figure 4.34

Remote Controlled Seafloor

Incremental Corer

4.4.2 Geodoff II (Figure 4.35)

Developed by Conrad-Stork, Haarlem, Holland and The Dutch Geological Survey Department, 1970 (Anon. 1970).

This system is capable of recovering 12 sequential lengths of 4 m long core from sediment or bedrock in water depths up to 200 m.

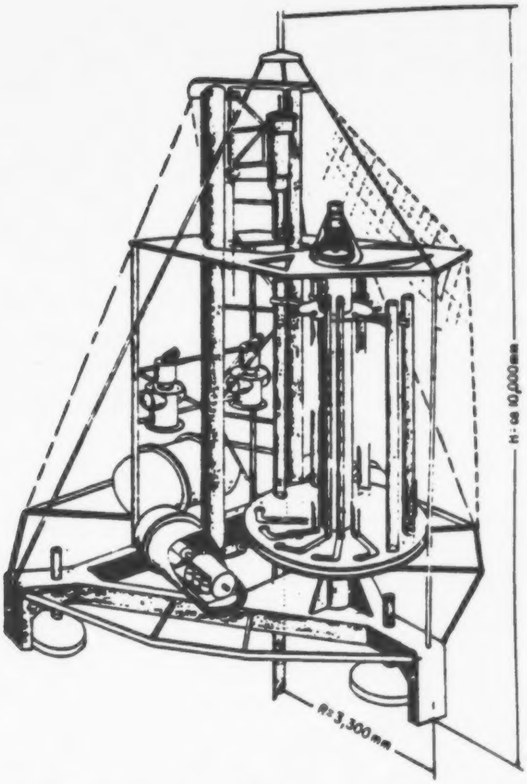
The Geodoff II consists of a 10 m high frame with a triangular base on a 3.3 m radius. The main body contains the rotary drilling device and a rotating supply disc on which the complete drill string is placed. The electric motor driving the hydraulic pumps, the computer, etc. are housed in drums on the main body. An umbilical cord from the surface vessel supplies electric power and electric signals. The core barrels are handled to and from the storage disc by means of mechanical arms.

When rotating clockwise, the front part of the core barrel is pushed into the ground ahead of the bit. Rotation in the opposite direction locks the core barrel inside the rotary bit. The amount of resistance from the soil results in the command to change from one direction to the other. The length of the protruding core barrel decreases with increasing soil resistance. When the barrel is pushed back completely into the rotary bit, only the direction of rotation has to be changed to lock the barrel in the bit and to adjust the cutting diameter in accordance with the core barrel capacity. If the progress indicator shows a high penetration speed again, it can be concluded that the hard layer has been drilled through. The direction is changed again, and the core barrel is unlocked and starts running ahead of the bit.

Recent modifications have converted the Geodoff II to a counter-flush coring rig. It is capable of sampling to 30 m in 1.5 m steps and weighs approximately 10 tonnes.

A double walled drill barrel is used with water being flushed down the annulus. The inner wall is constructed from light weight PVC. Soil samples are continuously flushed to the surface.

It is believed that the system is presently (1986) being used for gold placer exploration in Australia (Seacore 1986).



GEODOFF II. The main body, its three legs emplaced on the sea bottom, contains the rotary drilling device and a rotating supply disc on which the complete drill string is placed in 12 lengths of about 4 meters each. The electric motor driving the hydraulic pumps, the computer, etc. are housed in the drums on the main body. An umbilical cord from the surface vessel supplies electric power, electric signals and drilling mud. The filled core barrels are stored by mechanical arms after every pipe length of drilling progress. The tubes are placed on the supply disc in special clamps. After the hole has been completed, the drill string linking procedure is reversed and the drill pipes are returned one by one to their original positions on the supply disc.

Figure 4.35

Geodoff II

4.4.3 Koken Marine Drill (Figure 4.36)

Developed by the Koken Boring Machine Co. Ltd., Tokyo, Japan (Koken 1985).

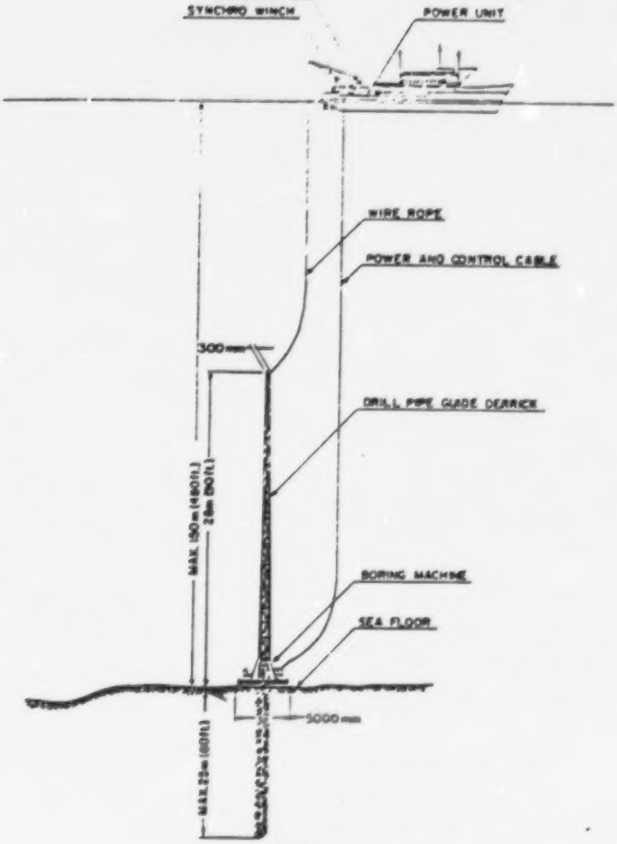
This system is capable of recovering 48 mm diameter cores, 24 m long from bedrock in water depths up to 150 m.

The unit consists of a 27 m high derrick mounted on a drilling platform having three legs with a width of approximately 5.0 m and length of 4.5 m. The platform can be leveled by adjustable hydraulic legs to ensure that the core hole is vertical.

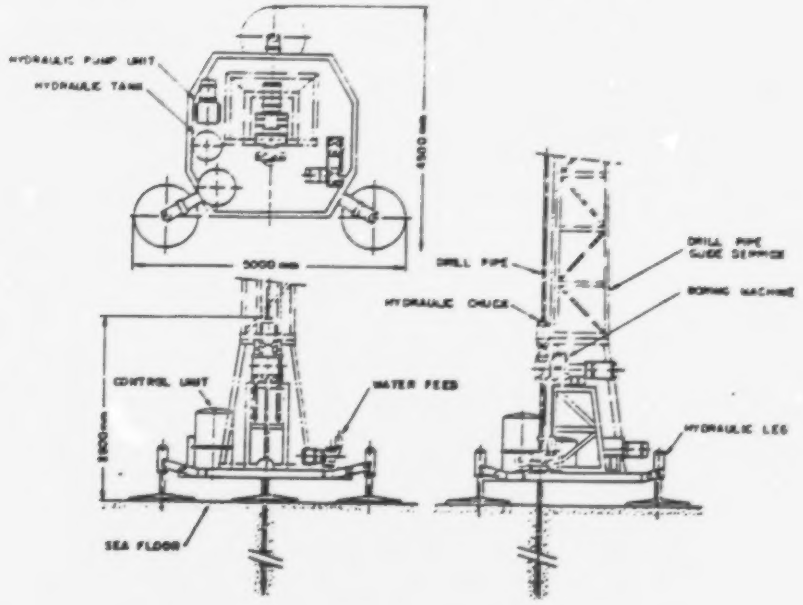
The boring machine, hydraulic pump and hydraulic tank, water feed pump, and control unit are all mounted on the seabed platform. Power for the drilling unit is supplied electrically from the surface by a combination power and control cable mounted on one drum of a two-drum winch. The other drum of the winch handles the steel support cable for lowering and hoisting the drill to the seabed. Three-phase submersible electric motors are mounted on the platform to power the various units.

The power for the motors is controlled by relays. Hydraulic circuits are controlled by solenoid valves and monitored by pressure transducers in each of the circuits which electrically telemeter pressure data to a surface control panel. The drill water pressure is monitored electrically by a pressure transducer at the surface. Drill feed length and rate are monitored by a synchromotor driven by a rack and pinion gear with a surface repeater.

Other models with different water depth and drilling depth capabilities are also available.


CONTROL BOX
SYNCHRO WINCH
POWER UNIT
WIRE ROPE
POWER AND CONTROL CABLE
300mm
DRILL PIPE GUIDE DERRICK
MAX 150m (480ft)
28m (90ft)
BORING MACHINE
SEA FLOOR
5000mm
MAX 25m (80ft)

–Koken marine drill.


HYDRAULIC PUMP UNIT
HYDRAULIC TANK
4500mm
5000mm
DRILL PIPE
DRILL PIPE GUIDE DERRICK
HYDRAULIC CHUCK
BORING MACHINE
CONTROL UNIT
WATER FEED
3800mm
HYDRAULIC LEG
SEA FLOOR

–Marine drill boring machine.

Figure 4.36
Koken Drill

4.4.4 ECSM2 (Figure 4.37)

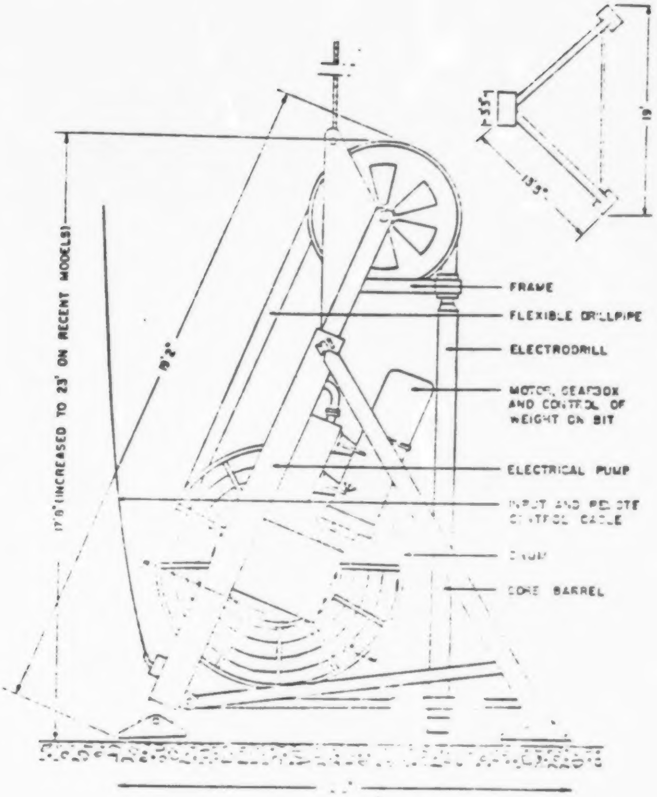
Developed by the French Petroleum Institute, Paris, France in 1965 (Le Tirant 1979).

This system is capable of recovering 90 mm diameter cores 1 m long, up to 30 m below the seabed in water depths up to 300 m.

The ECSM2 consists of a tetrahedral steel frame 7 m high, with a triangular base 5.5 m per side. This frame carries a storage drum on which is wound a 30 m length of flexible drill pipe. At the free end of the flexible pipe is attached a rigid joint consisting of an electric rotary drill with a 152 mm outside diameter, a core barrel and core catcher of conventional design with a working length of 1 m, and a diamond bit with a device for switching from 178 mm diameter full boring to 90 mm coring. The surface units consist of a power and remote control electrical cable handled by an electrically powered winch, a testing panel, and a control panel. The unit requires a power input of 100 kVA at 380V/50HZ, 3 phase.

The remote control panel on the surface permits the operator to check the level of the drilling frame with respect to the horizontal, displays the depth of the bit below the seabed, controls the weights of the bit and the drilling speed, regulates the drill water pump, and opens the bit to take the core sample.

The machine has been used almost exclusively in France and it is virtually unknown in the rest of the European geotechnical industry (Richards 1986).


17'8" (INCREASED TO 23' ON RECENT MODELS)
19'2"
5'5"
19'
13'3"
FRAME
FLEXIBLE DRILLPIPE
ELECTRODRILL
MOTOR, GEARBOX AND CONTROL OF WEIGHT ON BIT
ELECTRICAL PUMP
INPUT AND REMOTE CONTROL CABLE
DRUM
CORE BARREL

—*Layout of the ECSM2.*

Figure 4.37

French Petroleum Institute

ECSM2

4.4.5 Lockheed Rotary Corer (Figure 4.38)

Developed by Lockheed Missiles and Space Co., Sunnyvale, California, 1970 (Welling 1970).

This system is capable of recovering 51 mm diameter cores, 2.6 m long from soil and bedrock in water depths up to approximately 100 m.

The unit consists of a tubular aluminum frame 4.57 m high with four tripod feet on a 1.37 m radius. The frame encloses a carriage assembly which contains the drilling system, water circulation system, instrumentation switches, and retracting winch. In air the unit has a weight of 500 kg.

The drill motor is a 3 hp, 3600 rpm, 208 VAC, 60 Hz, 3 phase, submersible squirrel-cage induction motor. Coupled to this motor is a gear reducer which provides rotary drive at 100 rpm. Core barrel retraction is achieved with the use of the same gear reducer. A gearing system drives a winch drum which utilizes three pulleys and a 4 mm diameter 1/8 inch stainless steel cable to retract the core barrel.

Flushing water is provided to the drill tip by a 1 hp, 208 V/60 Hz, 3 phase submersible pump. The unit is oil filled and sealed to prevent entry of external fluid into the motor. A diaphragm mounted on the bottom of the motor allows pressure equilization.

Power is supplied from the support vessel via a separate umbilical. An operating console provides manual control from the surface and core barrel penetration along with power consumption can continually be monitored.

The rotary corer is designed to be operated from the deck of any ship having a 1-tonne crane.

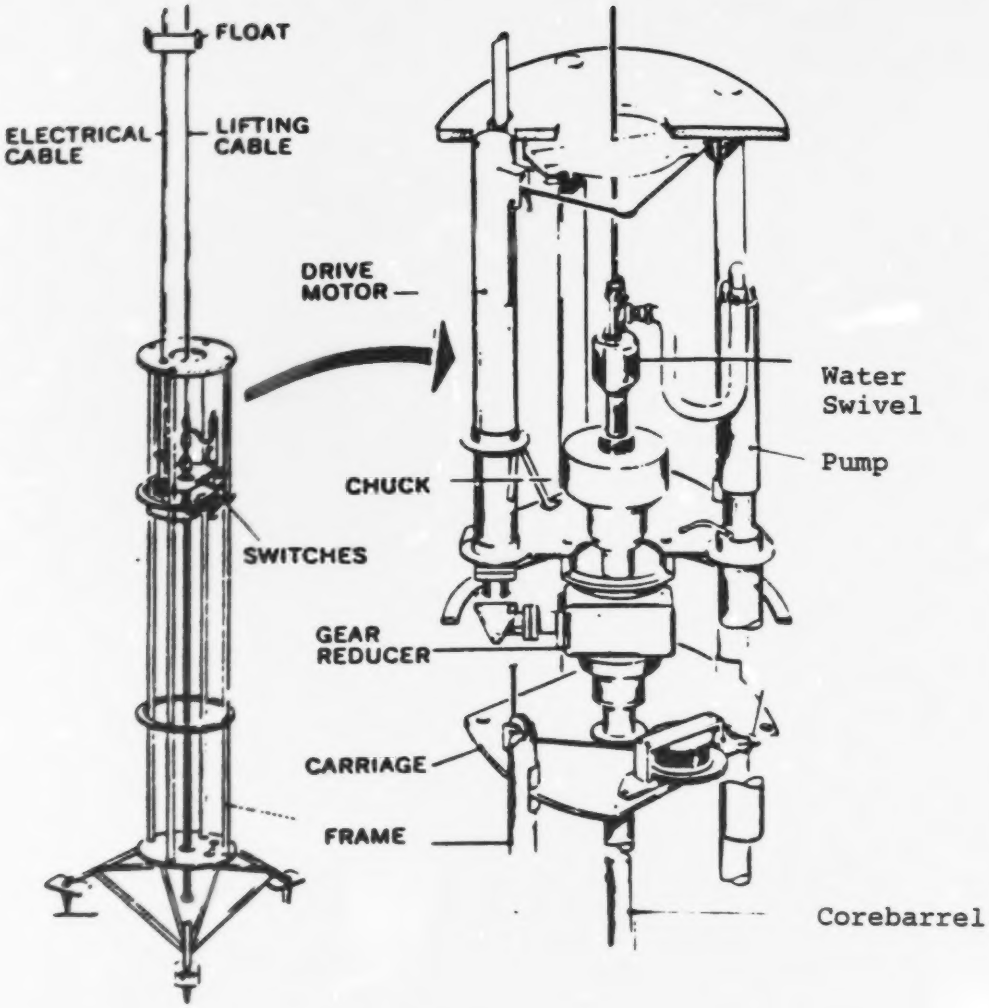

FLOAT
ELECTRICAL CABLE
LIFTING CABLE
SWITCHES
FRAME
DRIVE MOTOR
Water Swivel
Pump
CHUCK
GEAR REDUCER
CARRIAGE
FRAME
Corebarrel

Figure 4.38

Lockheed Rotary Corer

4.4.6 C-CORE Geotechnical Corer (Figure 4.39)

The geotechnical corer was developed by the Centre for Cold Ocean Resources Engineering at Memorial University in St. John's, Newfoundland in 1980-1981 (Christian 1984). Figure 4.39 shows the general arrangement of the main components of the corer. The assembly consists of a four-sided, pyramid-like framework which is lowered to the seabed from the operating vessel. The structure is free standing and connected to the vessel by power and control cables.

The drill is designed to recover 64 mm dia cores 1.5 or 3.0 m in length from overconsolidated sediment in water depths up to 150 m, using a standard H-size triple-tube core barrel together with a mud-flushing system.

The drilling unit is mounted on the central axis of the framework perpendicular to the base. The core barrel is mounted inside a sealed square kelly tube, and is rotated by means of a 15 hp submersible electric motor via a rotary table mounted on the drill base.

A seawater/drilling mud mixture is pumped into the upper end of the kelly tube to provide extension of the core barrel into the seabed. A controlled amount of the mud/water mixture flows through the face-discharge bit to cool the bit, flush away drill cuttings and also to provide a low-friction coating to the core to enhance sample recovery.

Retraction of the core barrel after the completion of drilling is provided by means of a hydraulic cylinder and a wire cable connected to the upper end of the core barrel.

To extract the core, the unit comprising kelly tube, core barrel, water swivel and bearing box is removed from the frame. The bit is removed to release the inner tube and the core is pumped out of the tube by means of a water connection made to one end of the inner tube. The pumping out of the core in this manner is a procedure used with standard triple tube core barrels.

A. Base frame
B. Side members
C. Top bearing support cradle
D. Top bearing box
E. Kelly tube
F. Main support pins
G. Drive motor mount
H. Lower bearing fallen
M. Rotary table pulley
P. Kelly drive plate
Q. Rocksheield
R. Fender
S. Pump support frame
T. Belt guard
U. Bottom kelly guard
V. Top kelly guard

1. Drive Motor
2. Gear Box
4. Sprocket
5. Belt
7. Bearing
8. Submersible Pump (GSW)
9. Water Swivel Assembly
10. Quik detachable coupling and hose assembly
11. Drill bit
22 Tie (1")

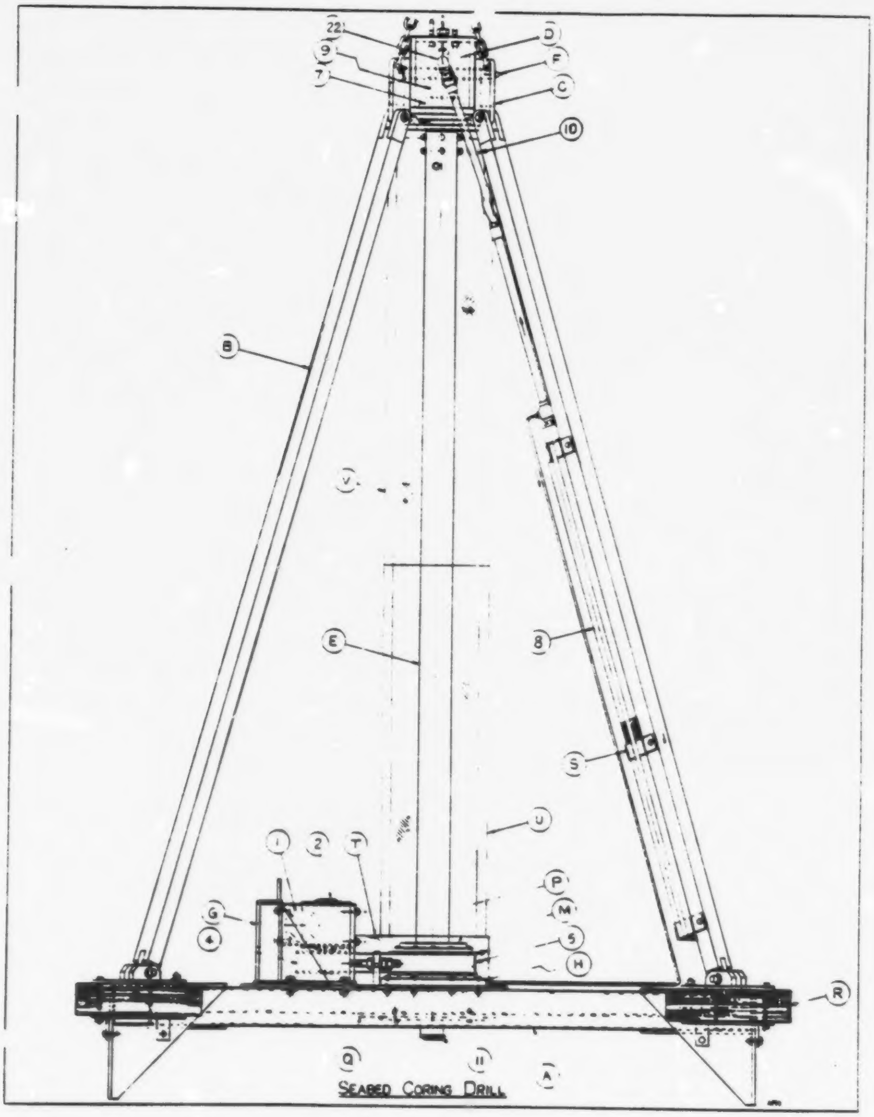

22
9
7
D
F
C
10
B
V
E
8
S
U
1
2
T
G
4
P
M
5
H
R
Q
11
A
SEABED CORING DRILL

Figure 4.39
C-CORE Geotechnical Corer

The drill has shown promise in trials to date but modifications to improve stability of the platform on the seabed, and the addition of instrumentation to monitor the drilling operations are considered necessary. It is understood that there are no plans at present for further development work on this system.

4.4.7 MD-300PT (Figure 4.40)

Developed by the Geological Survey of Japan, Marine Geology Department, Kawasaki, Japan, 1975 (Kinoshita et al 1977, Inoue et al 1978).

This system is capable of taking 36 mm diameter cores, 0.75 m long, from bedrock, in water depths up to 300 m.

The drill unit consists of a tetrahedral-shaped frame constructed from tubular sections, fitted with two circular rings. It is 2.3 m high, 2.0 m in diameter and weighs 1070 kg in air.

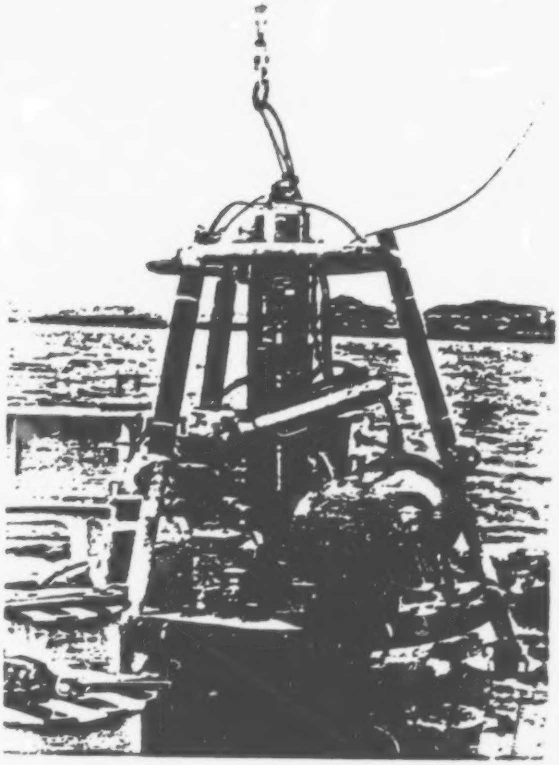
The mechanism also consists of (1) submersible motor, (2) battery unit, (3) control panel, (4) drill head and water supply pump, (5) pressure balancing device and (6) bit and double-tube core barrel.

The MD-300 PT is a fully automatic, battery-sustained system. The motor drives the drill head by a shaft with rotation speed reduced by the reduction gear. The motor simultaneously drives the water pump. The reduction gear transmits thrust power to the drill head by means of a sprocket and chain. When drilling is completed, the motor commences rotating in reverse and the drill head travels backward. Should a problem arise, such as overloading of the motor, battery failure, tilt or upsetting of the drill, the core barrel is automatically retracted thus ensuring complete safety of operation.

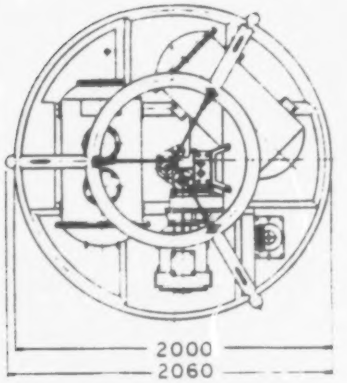
The drill was successfully deployed from the research vessel "Haklirei-Maru" (87 m long) and operated under a current of 1.5 knots in Sagami Bay south of Tokyo.

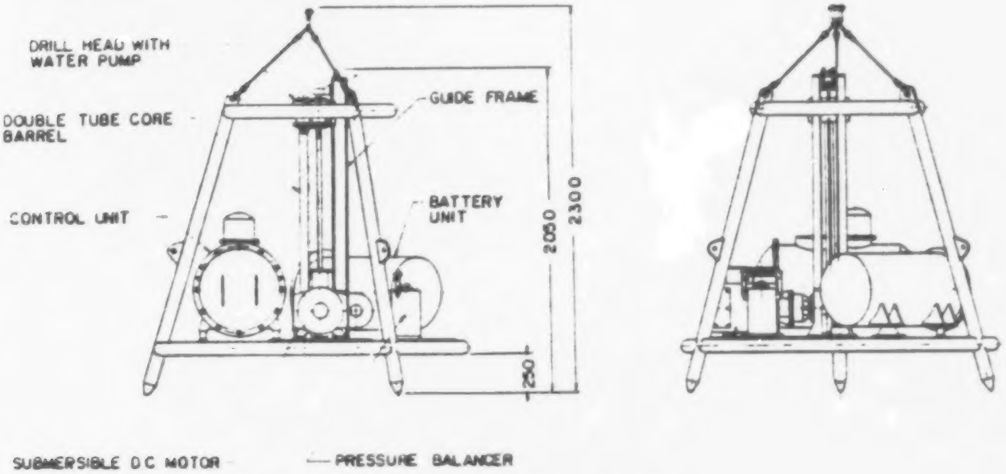
SPECIFICATIONS

MODEL	MD-300PT "PORTABLE MARINE DRILL"
METHOD	SUBMERSIBLE CORE DRILL I CYCLE AUTOMATIC DRILLING BY DC MOTOR & BATTERIES
WATER DEPTH & SEA CURRENT	300 m , 3kt
SAMPLE	DIA. 36 mm , LENGTH 750 mm CORE
BIT SPEED	450 rpm
PENETRATION	LOAD MAX. 300kg SPEED 10 cm / min STROKE 100cm
POWER	DC SUBMERSIBLE MOTOR, BATTERIES 48 V
WEIGHT	IN AIR 1070 kg , IN WATER 560 kg



Submerged rock drill MD-300PT machine with Benthos model 2214 pinger.




DRILL HEAD WITH WATER PUMP
DOUBLE TUBE CORE BARREL
CONTROL UNIT
GUIDE FRAME
BATTERY UNIT
2050
2300
250
SUBMERSIBLE DC MOTOR
PRESSURE BALANCER

Submerged rock drill MD-300PT and the specifications (in mm).

Figure 4.40

MD-300PT

4.4.8 Woods Hole Institute of Oceanography Rock Drill

Developed by Woods Hole Institute of Oceanography, MASS., 1975 (Ryall 1980).

This system is capable of recovering up to 1 m of rock core, 19 mm in diameter, after penetrating up to 1 m of sediment. The unit has a maximum operating depth of 4000 m.

The drill is 2.9 m high and 2.9 m across its widest dimension, with a weight of 860 kg air. It is driven by a 36 VDC, 5 hp electric motor during drilling, and uses a separate 1/4 hp motor to drive the retract pump. Three automotive type, 12 V batteries provide up to 24 minutes drilling time. The drill is lowered from the ship on a torque - balanced wire rope.

4.4.9 NORDCO Electric Rock Core Drill (Figure 4.41)

This drill was originally developed by the Bedford Institute of Oceanography, Dartmouth, Nova Scotia in the early 1970's and is currently manufactured and marketed by NORDCO Limited. The system is capable of taking 25 mm diameter cores, 5.75 m long from bedrock in water depths of up to 600 m. A modified version of the drill can core to a depth of 9.15 m below seabed. A high-voltage (2400 VAC) deepwater version is also available which is suitable for operation in water depths up to 3,500 m. The drill is composed of the following three major components: frame, drill barrel assembly and drive mechanism.

The frame is constructed from aluminum structural section and forms a tetrahedron shape approximately 2 m on a side. It forms a stable platform for drilling and is structured to provide mechanical protection for the drive mechanism as well as a rigid attachment for the drill barrel assembly and umbilical cable. The frame is supported on three spade-like legs and is ballasted with lead to give a weight of 1000 kg in air.

The drill barrel assembly is composed of three concentric tubes: an inner steel core barrel, an intermediate plastic tube which controls vertical movement of the core barrel, and an outer aluminum mast which houses the inner rotating tubes and transmits downloads from the core barrel/plastic drive tube through a thrust race to the drive mechanism and the frame by means of the guy wires which attach it to the outer extremities of the frame. The mast also acts as a conduit for flushing water which is transmitted to the flange assembly at the top of the mast by a plastic hose. The mast is attached to the top of the frame by a swivel attachment which, when freed, allows it to swing out for replacement of the core barrel and plastic drive tube.

The single tube core barrel is either a 6.1 m or 10.1 m long. EXT size drill rod with a reaming shell, core catcher and EXET diamond bit mounted with left-hand threads at its lower extremity. The core barrel penetrates the sea bottom and takes a 25 mm diameter core. The core barrel has an outer vertical keyway which runs its full length. The keyway mates with a keyed drive flange in the drive mechanism which imparts rotary motion to the core barrel.

A threaded brass bolt at the upper end of the core barrel engages an internal thread which runs the full length of the plastic vertical drive tube and imparts up or down motion to the core barrel depending on the direction of rotation of the main power drive and the relative rotational speeds of the core barrel bolt and the plastic vertical drive tube. These rotation rates are fixed but different rotation speed ratios are used during drilling and retraction operations.

The standard bit rotation speed under no-load conditions is 1,294 rpm and the bit extension rate (no load) is 183 mm/minute. To retract the corebarrel the main drive rotation direction is reversed and this disengages the rotary drive to the drill barrel by means of a one-way clutch. This increases the relative rotational speed between the core barrel bolt and the plastic vertical drive tube and provides a (no load) barrel retraction rate of 3.5 m/min.

The drive mechanism is housed in a free-flooding but enclosed gear box and has the primary function of imparting both rotational/axial motion to the core barrel while drilling or axial motion when retracting the core barrel from the hole. The system is driven by a 5 hp, 3-phase submersible induction motor.

Drill flushing pressure, drill tilt on two axes, motor current and core barrel extension and retraction rates are displayed at the surface during drilling operations.

The drill has been operated extensively off Canada's eastcoast and the coast of Norway and Australia. Success has been achieved in obtaining rock cores, however the drill is not designed to recover samples of overburden.

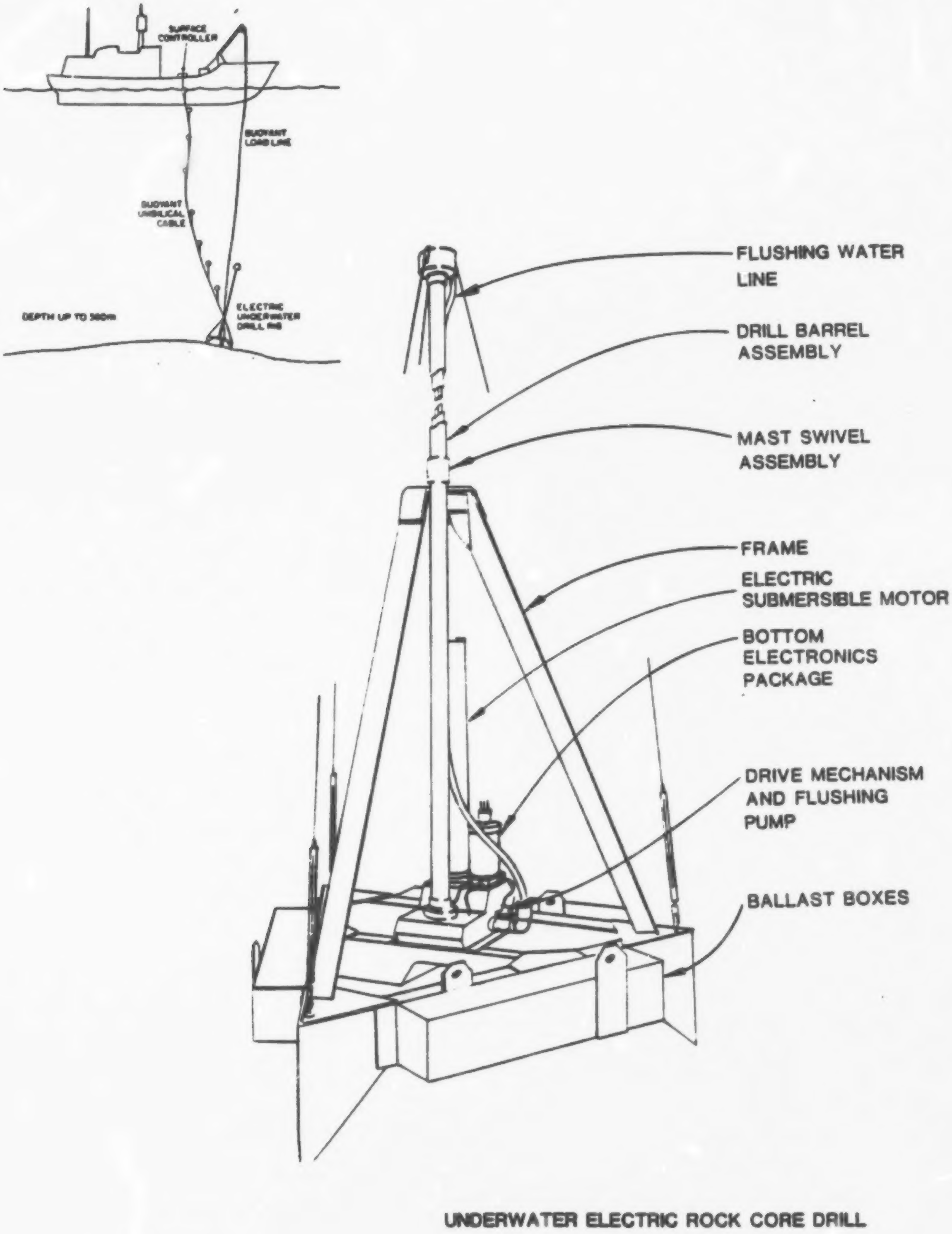

SURFACE CONTROLLER
BUOYANT LOAD LINE
BUOYANT UMBILICAL CABLE
DEPTH UP TO 360m
ELECTRIC UNDERWATER DRILL RIG
FLUSHING WATER LINE
DRILL BARREL ASSEMBLY
MAST SWIVEL ASSEMBLY
FRAME
ELECTRIC SUBMERSIBLE MOTOR
BOTTOM ELECTRONICS PACKAGE
DRIVE MECHANISM AND FLUSHING PUMP
BALLAST BOXES
UNDERWATER ELECTRIC ROCK CORE DRILL

Figure 4.41

NORDCO Electric Rock Core Drill

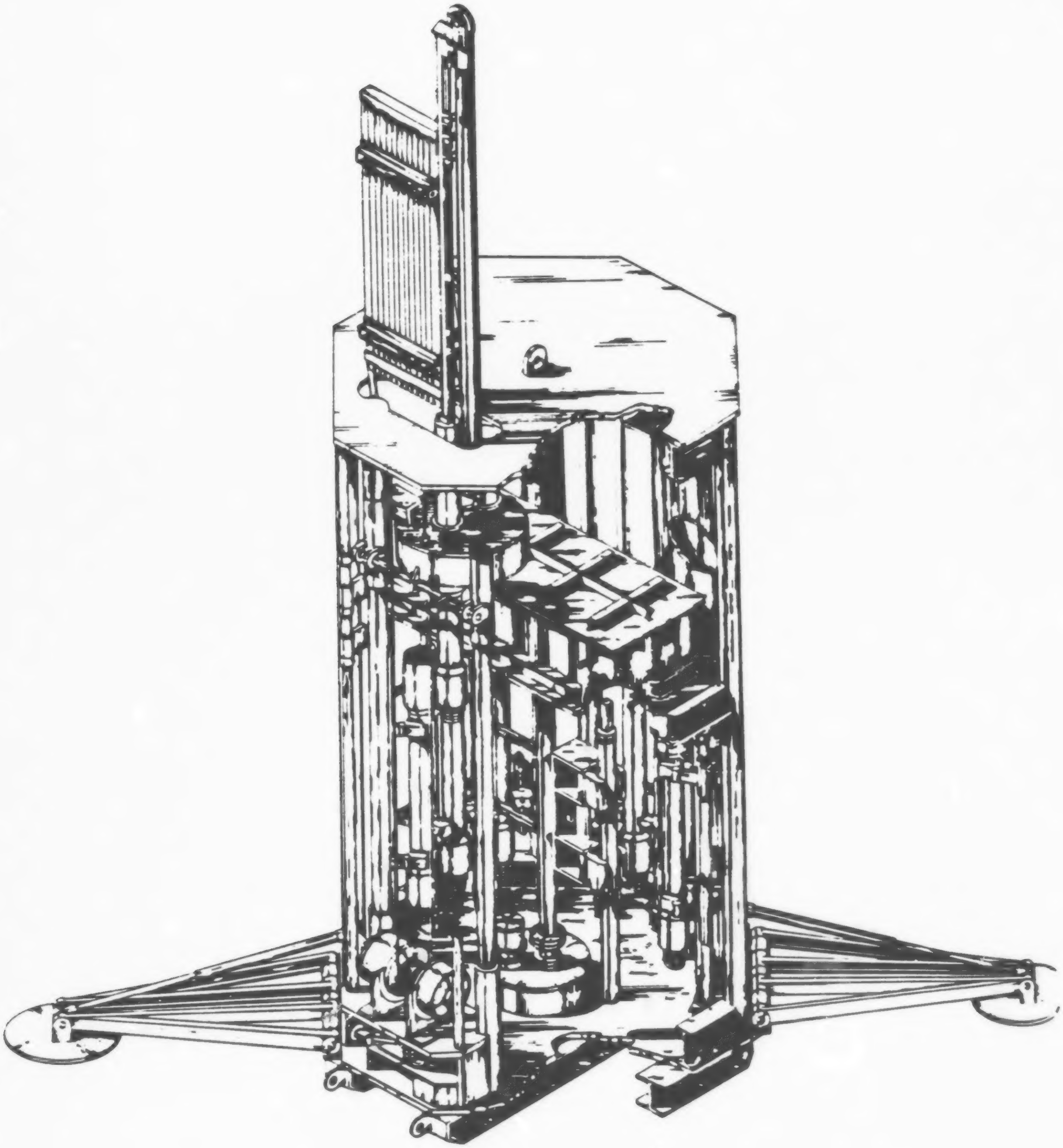
4.4.10 Texas A & M Seacore 50 (Figures 4.42 and 4.43)

Developed by Texas A and M University, 1971 (Bailey et al 1971).

This system was intended to be capable of taking 76 mm diameter cores, 15 m long from virtually any material varying from soft marine mud to sand to hard rock in water depths up to 300 m.

The unit is octagonal in cross-section measuring 1.83 m side to side and is 3.66 m in height. When the unit reaches the seafloor, four legs fold down (4.88 m spread) and level the unit on slopes of up to 15°. The unit weighs 4600 kg in air and is lowered to the seafloor by a single electro/load umbilical cable. An automatic control system is contained in the unit with shipside manual control available at any time. A 10 hp electric motor drives two hydraulic pumps which deliver power to the hydraulic powerhead. This powerhead produces 1370 N-m of torque and drives a drill pipe fitted with a ring-type core bit.

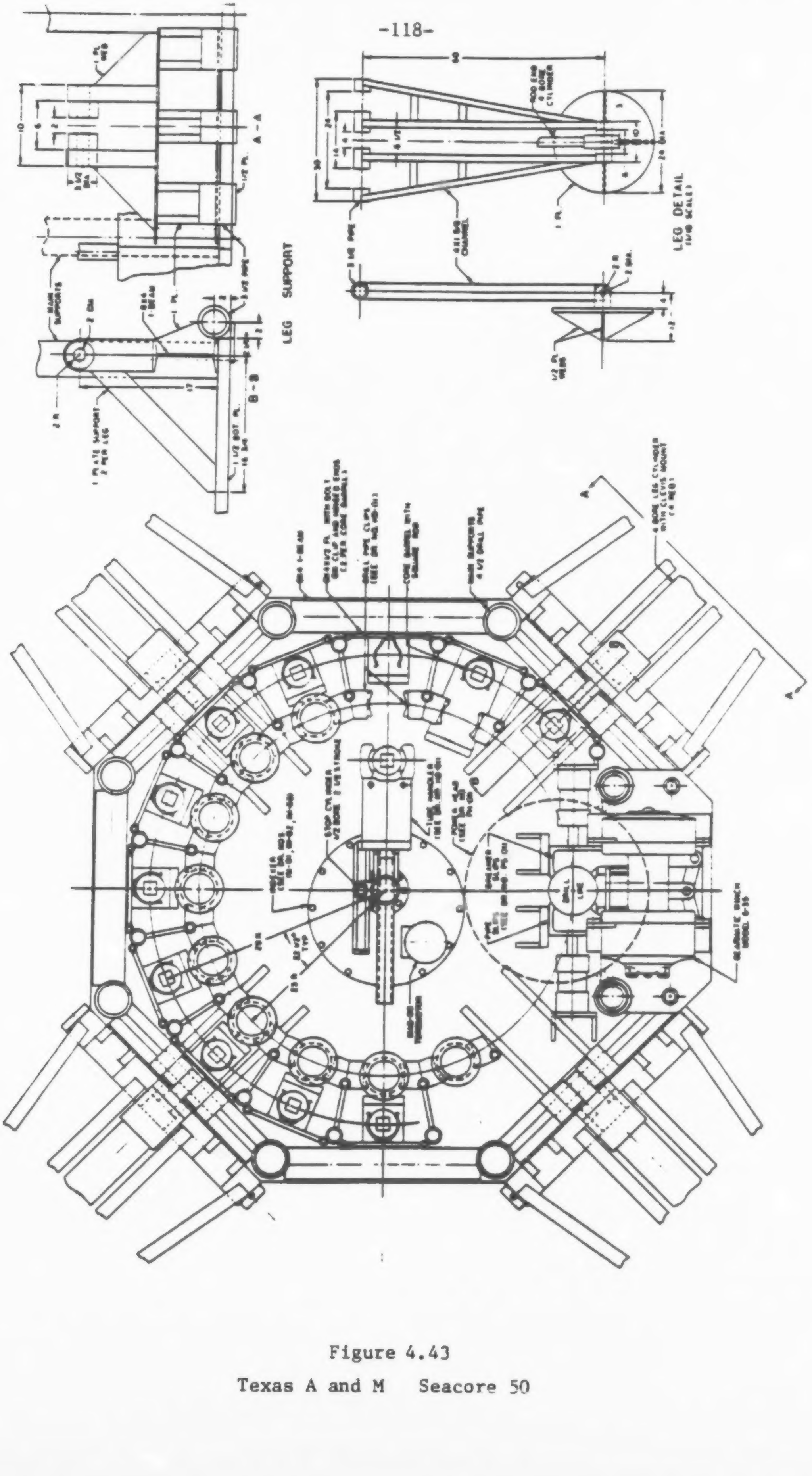
This unit was only conceptually designed and was never constructed (Richards 1986).



Texas A&M U. automatic marine corer.

Figure 4.42

Texas A and M Seacore 50


LEG SUPPORT
A-A
B-B
LEG DETAIL
DRILL LINE

Storage compartment plan and leg detail.

Figure 4.43

Texas A and M Seacore 50

4.4.11 HYCO Slack Line Corer (Figure 4.44)

Developed by International Hydrodynamics Co. Ltd., North Vancouver, B.C.

This system is capable of recovering 41 mm diameter cores 3.0 m long from bedrock in water depths up to 200 m. It has a weight of 920 kg in air (McFarlane and Trice 1972).

The Hyco drill consists of a rectangular frame having two vertical pillars on which the main housing slides. Within this unit is mounted the electro-mechanical rotary drive which has a 10 hp, AC motor as its prime mover. Power is supplied from the support vessel at 440 V, 3-phase, 60 Hz, via a single electro/load umbilical. The system comes complete with instrumentation which includes, salt water leak detector, tilt indicator, tachometer and drill feed rate.

The drill was successfully used in Hudson's Bay in 1972, being deployed from the support vessel "MV Hudson Handler" (length 27.5 m).

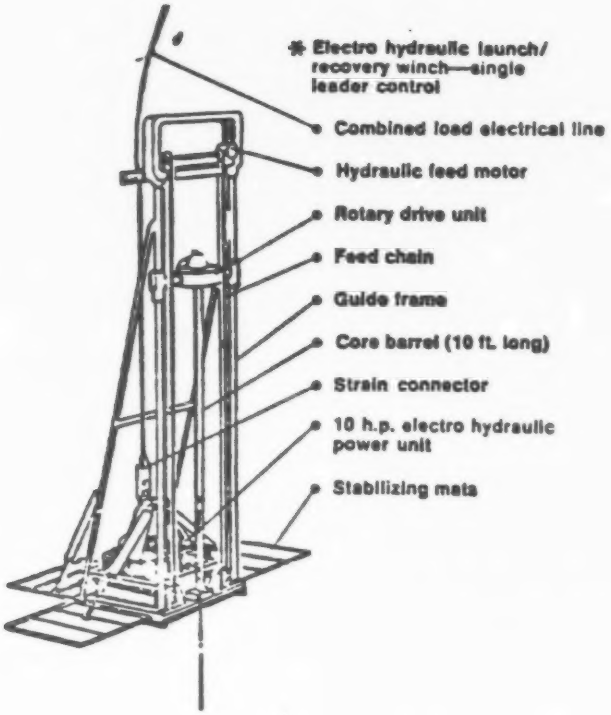

* Electro hydraulic launch/ recovery winch—single leader control
Combined load electrical line
Hydraulic feed motor
Rotary drive unit
Feed chain
Guide frame
Core barrel (10 ft. long)
Strain connector
10 h.p. electro hydraulic power unit
Stabilizing mats

Figure 4.44

HYCO Slack Line Corer

4.4.12 Terrasearch Seabed Sampler (Figure 4.45 and 4.46)

This system was developed by Terrasearch Ltd. in Great Britian during 1974-1975. The sampler has a base area of 4.5 m x 3.0 m and an overall height of 11.0 m. The complete unit weighs 9 tonnes in air and is hydraulically operated (Anon 1978, Anon 1979).

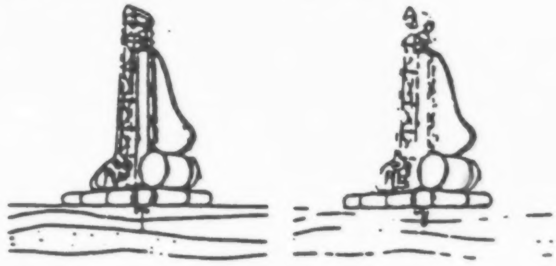
The sampler can be operated in 300 m of water while cutting cores to a depth of 10 m. Before drilling operations begin, a hydraulically powered electronic penetrometer probe is thrust into the soil. After the penetrometer is pushed to a depth of 1.5 m below the drill barrel a core tube is thrust down beside the penetrometer probe to a depth of 1.0 m below the drill barrel. Both penetrometer and core tube are then retracted.

Following this, drilling starts by rotating the drill barrel while at the same time a continuous chain feed winch unit on the mast of the drill applies a downward vertical force. After the drill barrel is 1 m into the soil, drilling is stopped and the penetrometer and core tube are again thrust into the sediment. This sequence can be repeated up to 10 times at any drill location to give a total penetration of 10 m. During drilling, the drill head is flushed continuously with sea water to remove silt and mud and to lubricate moving parts.

Hydraulic power is transmitted to the drilling head through an umbilical hoseline incorporating seven tubular passages, for high and low pressure oil flow, and an electric cable. Working pressure at the drilling head is 280 bar.

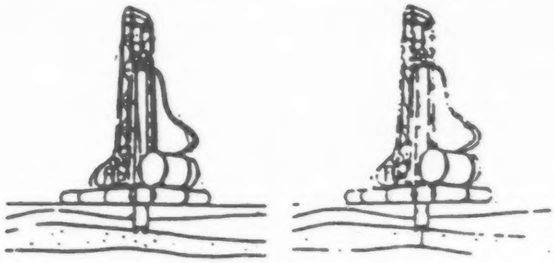
First penetrometer test to 1.5-m depth.

Jack in first sample tube to 0.9-m.



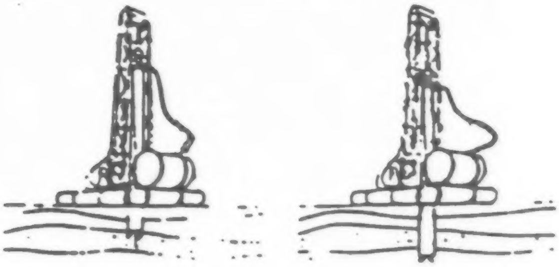
Retract penetrometer and sample tube then rotary drill to 0.9-m.

Second penetrometer test 0.9-m to 2.4-m.



Second sample tube 0.9-m to 1.8-m.

Repeat sequence to full depth of 9 meters.



How the deepwater sampler works.

Figure 4.45

Terrasearch Seabed Sampler

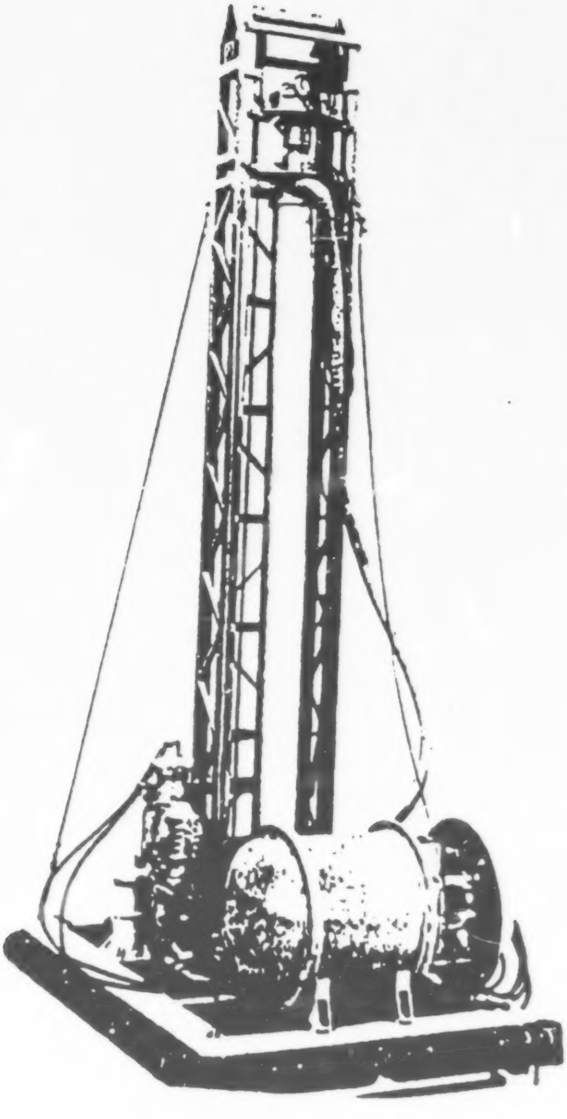


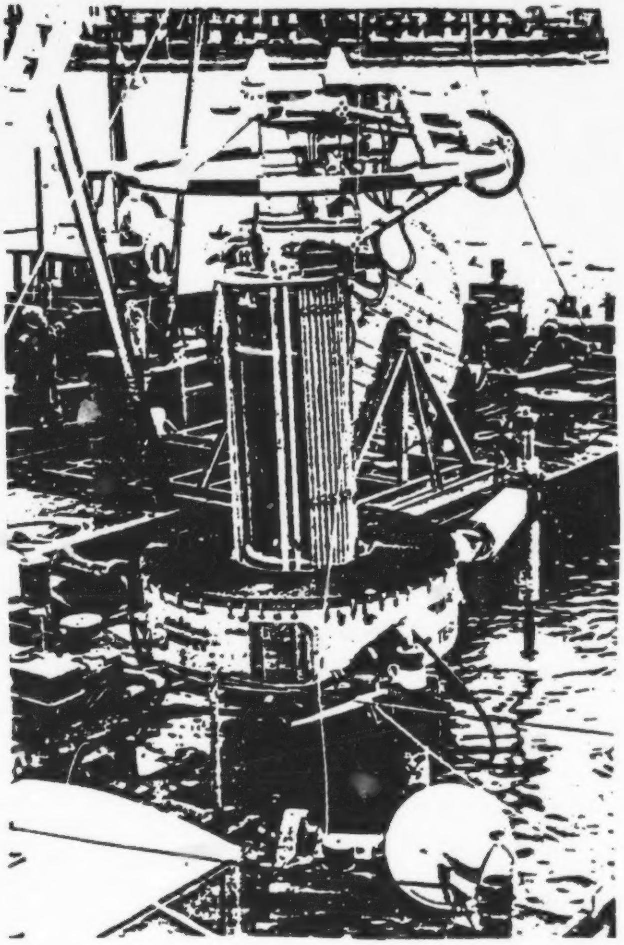
Figure 4.46

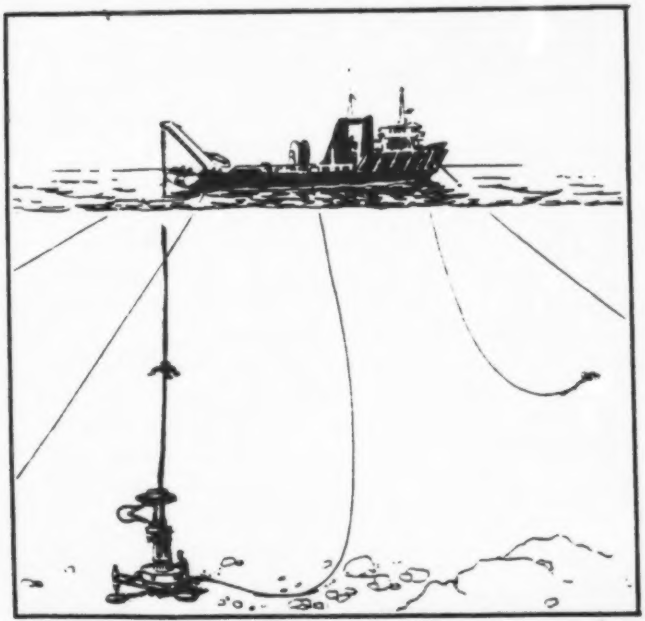
Terrasearch Seabed Sampler

4.4.13 Atlas Copco and Wimpey - Maricor Sampler (Figure 4.47)

Maricor is a remotely controlled drill developed jointly by Atlas Copco and Wimpey Laboratories in the early 1970's. The machine weighs 14 tonnes in air and is capable of operating in water depths to 200 m and takes individual cores 2.2 m long and 57 mm diameter up to 60 m below the seabed (Anon 1973).

The system uses diamond core drilling and wire line recovery techniques to enable the sample to be withdrawn through the centre of the drill rods. A single electrical umbilical provides power for the electro-hydraulic operation. The sampler was tested in Locke Linnhe, Scotland and has worked in water depths up to 65 m, while drilling boreholes from 18 m to 33 m through peat, clay, pebbles and rock.





ABOVE: Maricor can operate in water depths up to 200 m, from a vessel which does not have to be specially designed for drilling. Here the sample carrier is returning to the surface after delivering an empty inner core barrel to the machine.

Figure 4.47

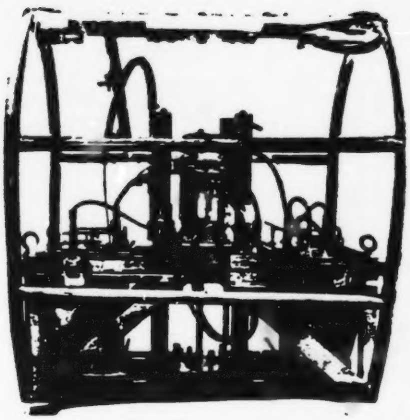
Atlas Copco and Wimpey - Maricor Sampler

4.4.14 Harrison Hard Rock Corer (Figure 4.48)

This system is capable of recovering 10 mm diameter cores 0.25 m long from bedrock in water depths up to 150 m (Eden et al 1970).

The unit consists of a 1 cubic m frame and weighs 160 kg in air. Its small size and light weight enable it to be handled from small inshore vessels.

The DC drill motor is powered by two 6 V lead-acid batteries. It drills under its own weight on command from the operator, who can select the target and monitor the operation using a TV camera mounted within the drill frame.



The Harrison Hardrock Corer, showing batteries, drill motor and hydraulics. Width of frame approximately 1 m.

Figure 4.48

Harrison Hardrock Corer

4.4.15 Conrad Drills (Figures 4.49 and 4.50)

Manufactured by Conrad (formerly Conrad-Stork) of the Netherlands and now marketed by Arkana Europe B.V. of Amsterdam (Arkana - Undated).

The original hand-operated (Banka) drill was developed for onland prospecting and can be used from a floating platform in shallow, protected waters. Total drilling depth (water depth plus depth of penetration below seabed) is limited since all drilling operations, including withdrawal and hoisting of casing, is performed manually with a drill crew of up to 10 labourers.

A cable-tool percussion rig (Model PP150) with a hydraulic rotary table is also available. Ths equipment can be used from a floating platform in shallow waters. Total drillstring depth (i.e. water depth plus depth of penetration below seabed) is limited to about 50 m. To provide torque reaction to rotate the casing, the rotary table has to be anchored to the seabed or to the anchored rotating platform. Casing is normally 100 or 150 mm.

The cable-tool percussion drilling methods widely used in U.K. are similar in principle to the Conrad-Stork PP 150. With these systems the casing (normally 150 or 200 mm diameter) is either mechanically rotated or hammered into the ground and is subsequently withdrawn by winch and cable.

Seacore Limited of U.K. has carried out extensive prospecting for tin in Cornwall, England, for Billiton Minerals (U.K.) and GOPENG Consolidated using this system in alluvial swamp deposits and offshore (Seacore 1986).

A more recent development by Conrad-Stork is the introduction of the 100 mm and 114 mm double tube counterflush (or reverse circulation) drilling system. With this system a double walled tube, with a drill bit at its lower end, is rotated into the ground. Flushing water is pumped down the annulus between the inner and outer tubes and returns to the surface up the inner tube carrying with it a near-continuous (disturbed) sample of drill cuttings.

When drilling in clay or harder formations, a saw-toothed cutting shoe can be used together with a chisel to break up the material.

For handling the drillstring in offshore work, use of a 7 m high A-frame is necessary. The A-frame carries a working platform about 2.4 m above deck level to facilitate the addition and removal of drillpipe sections as necessary.

This system has been used in Indonesia, Malaysia and Thailand for tin exploration in water depths of 5 to 25 m. Drilling depths below seabed have often been in the 30 to 40 m range.

A penetration rate of 1 m/min in soft alluvial formations is quoted as normal for on land operations to 15-20 m depth with the counterflush drill system.

In addition to the drill and the A-frame mentioned above, ancillary equipment required for offshore work includes anchor winches, complete with a power unit, hydraulic pumps, hydraulic control panel, piping and hoses, and high pressure water pump with hoses and connectors.

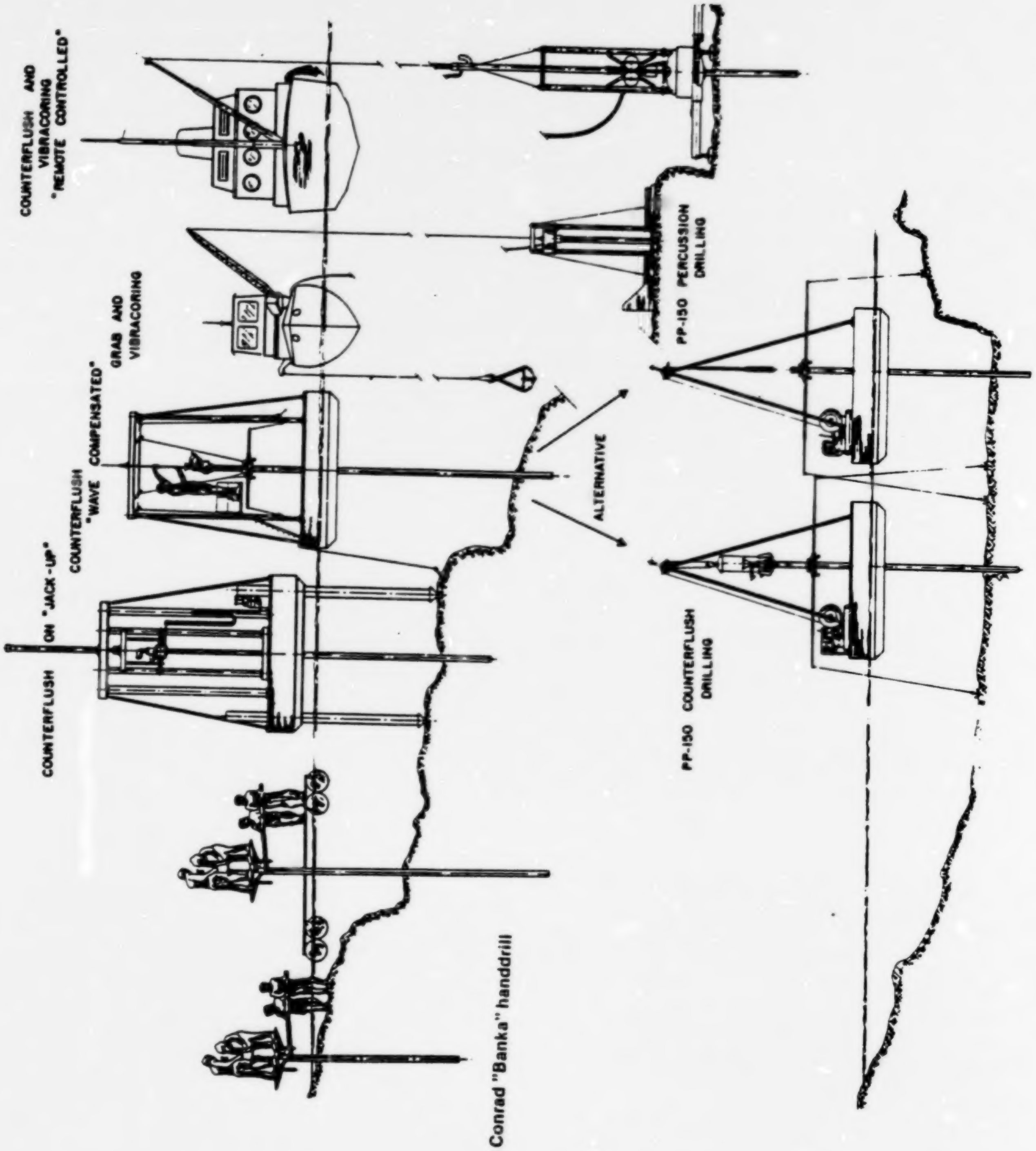

COUNTERFLUSH AND VIBRACORING "REMOTE CONTROLLED"
GRAB AND VIBRACORING
COUNTERFLUSH "WAVE COMPENSATED"
COUNTERFLUSH ON "JACK-UP"
PP-150 PERCUSSION DRILLING
ALTERNATIVE
PP-150 COUNTERFLUSH DRILLING
The Conrad "Banka" handdrill

Figure 4.49
The Conrad series of drills

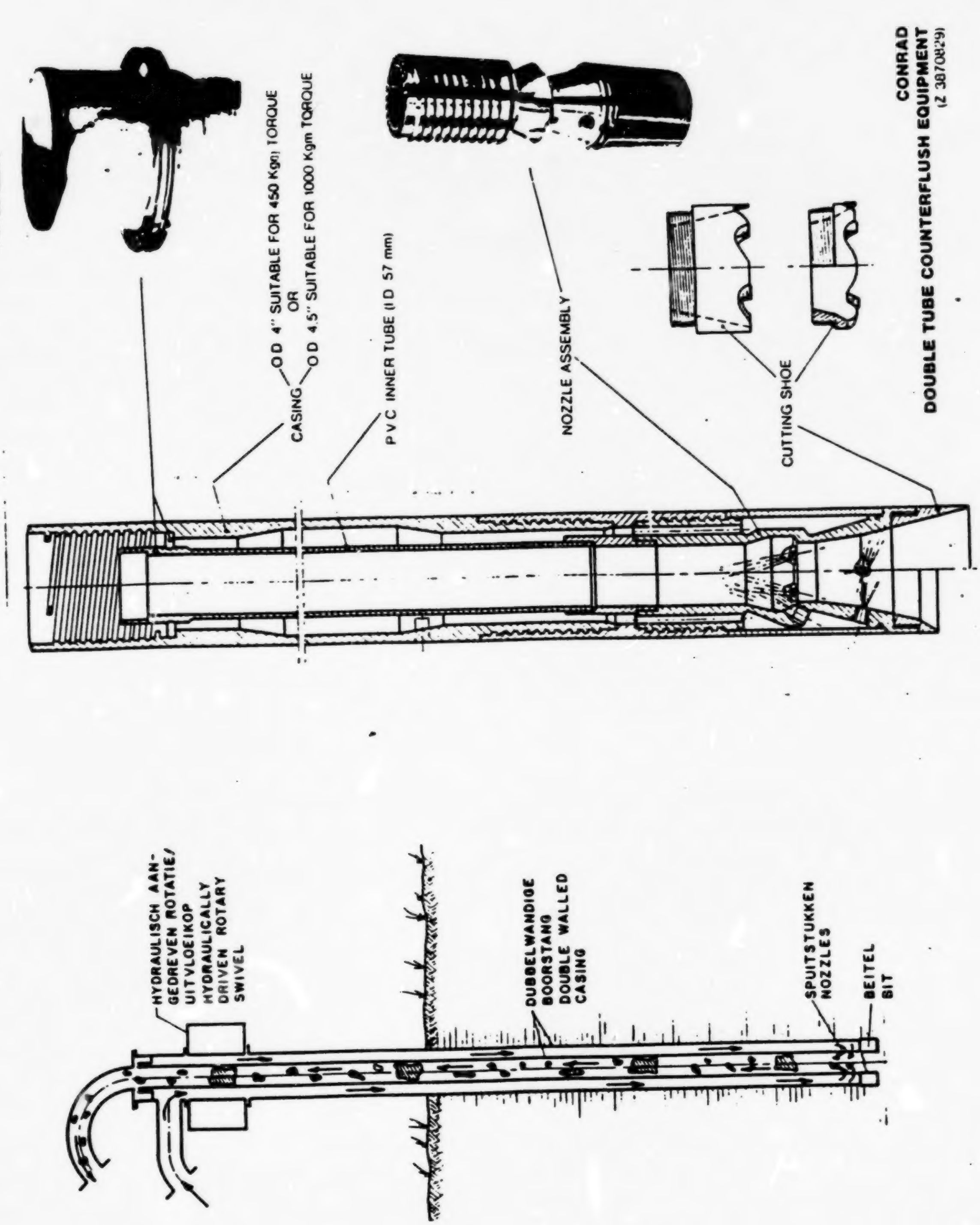

OD 4" SUITABLE FOR 450 Kgm TORQUE
OR
OD 4.5" SUITABLE FOR 1000 Kgm TORQUE
CASING
PVC INNER TUBE (I D 57 mm)
NOZZLE ASSEMBLY
CUTTING SHOE
CONRAD
DOUBLE TUBE COUNTERFLUSH EQUIPMENT
(Z 3870829)
HYDRAULISCH AANGEDREVEN ROTATIE/UITVLOEIKOP
HYDRAULICALLY DRIVEN ROTARY SWIVEL
DUBBELWANDIGE BOORSTANG
DOUBLE WALLED CASING
SPUITSTUKKEN
NOZZLES
BEITEL
BIT

Figure 4.50

Conrad Counterflush Drilling Equipment

4.4.16 Underwater Frame BSM 12 (Figure 4.51)

Developed by CREO in La Rocelle, France. Available details are sparse, but this equipment is believed to have both rotary coring and vibrocoring capability (CREO Undated).

The unit can take 12 m long cores, 115 mm diameter of a wide range of soils in water depths up to 100 m. It is 3.65 m high (without drill pipe), 5.70 m wide and weighs 5 tonnes.

It uses the vibrohammer principle (together with rotary boring?) to achieve penetration. It is hydraulically driven from the support vessel and requires 48 kw of power to the hydraualic power pack. All relevant functions can be monitored from the surface and the system includes a TV monitor.

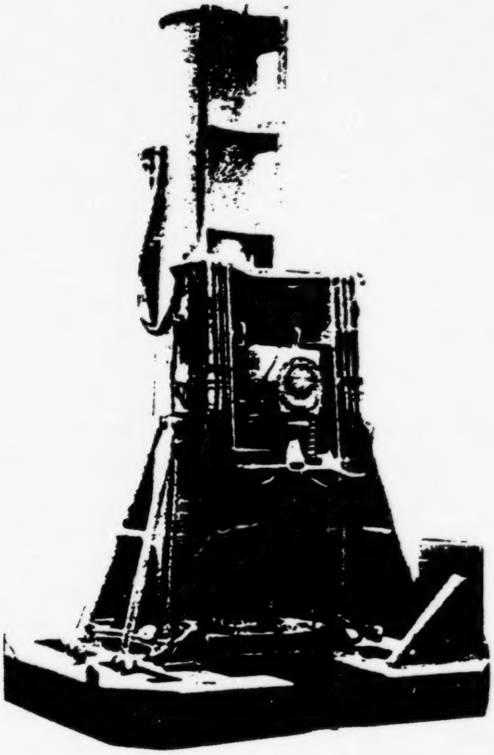


FIGURE 4.51 C.R.E.O. Underwater Frame BSM 12

4.4.17 DGD - 2000 Motion Compensated Deep Geotechnical Drill (Figure 4.52)

Developed by Mobile Augers and Research Ltd. in 1981 with assistance from Seacore Ltd. (Burgess et al 1983, Mobile Augers 1983).

The unit is a motion compensated, rotary, top-drive drill tailored specifically for Beaufort Sea use. The unit uses a Christensen drill pipe to drill to required depths and then take 75 mm diameter samples up to 1.5 m long with a hammered split spoon sampler. Initial samples could be taken with Shelby tubes. The system is capable of sampling in up to 600 m of water.

A clump weight tension leg motion-compensating system is used in conjunction with a 2 m stroke hydraulic ram and a nitrogen-activated accumulator, which reduces drillstring motion to ±3 mm per meter of vessel heave. Operation of the heave compensating system requires the placement of a 10 tonne clump weight on the ocean floor.

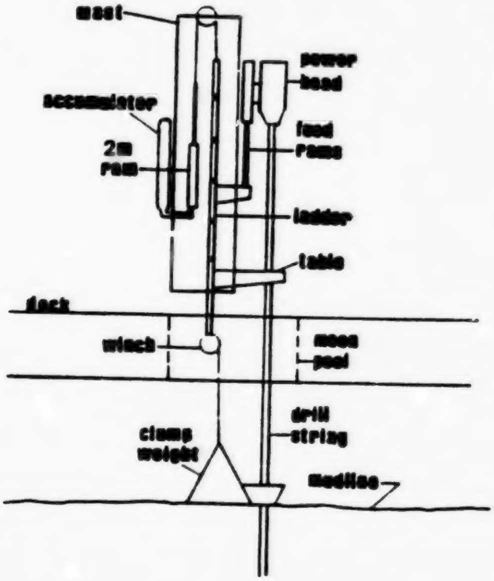
Drilling is accomplished by use of Damco 2000 drawworks. The power train, control system, mast and mud pumping system are standard equipment supplied by Mobile Augers and Research Limited.

The unit has a gross weight of 18 tonnes, excluding the clump weight and requires 4.5 m x 14 m of deck space and a 2.4 m x 2.4 m moon pool. All power requirements are supplied independently of the ship's equipment.

The system was used successfully in the Beaufort Sea to carry out geotechnical investigations for proposed caisson-retained islands and performed well. Drilling was carried out from a 55 m anchor handling tug equipped with a moonpool.

The designer does not consider that the drill is suited for use in long high swells as might be found offshore Nova Scotia.

The unit costs $5,000 - $10,000/day to lease. If a program required use for more than three months then the rate would be calculated near the lower end of this range (Mobile Augers 1986).


mast
power
head
accumulator
feed
rams
2m
ram
ladder
table
deck
winch
moon
pool
drill
string
clamp
weight
mudline

Heave compensation (schematic).

Figure 4.52

D.G.D. - 2000
Motion Compensated Deep
Geotechnical Drill
(Schematic)

4.4.18 SEASAM (Seabed Sampler) (Figure 4.53)

Developed in 1980 by the Central Research Department (Netherlands) of Osiris - Cesco and Land and Marine Engineering (Anon, Date Unknown; de Haas 1983).

The SEASAM is capable of taking 100 mm diameter cores, 6 m long, from both bedrock and sediment, and carrying out in situ cone penetration tests in water depths up to 200 m.

The system consists of a basic 9 m high frame, standing on three adjustable legs, weighing 5.6 tonnes in air without ballast. Ballast is needed to carry out in-situ cone penetrometer tests.

The required 25 kw of power is supplied via a secondary umbilical cable which connects the device to a control panel allowing the sampler to be electronically operated from a support vessel. The control panel is equipped with instruments for displaying water depth, distance to the seabed, penetration speed, depth in the seabed, and the drill's rotary speed. All data can automatically be recorded on a strip chart recorder.

Power is provided to an electro-hydraulic drive which is installed in a watertight box called a 'central pod'. Either the drilling pipe and motor, the soil sampling pipe or the cone penetrometer can be suspended from a trolley which moves up and down the frame to provide penetration and retraction of the drilling/sampling/testing tools.

One of the key features of the system is its portability. It can be easily broken down into six components: three adjustable legs, the central pad and a two section mast.

The corer was tested in Libya and during a 22 day period drilled 125 m. The system has since been successfully used in Dekhelila, Egypt, for a harbour project.

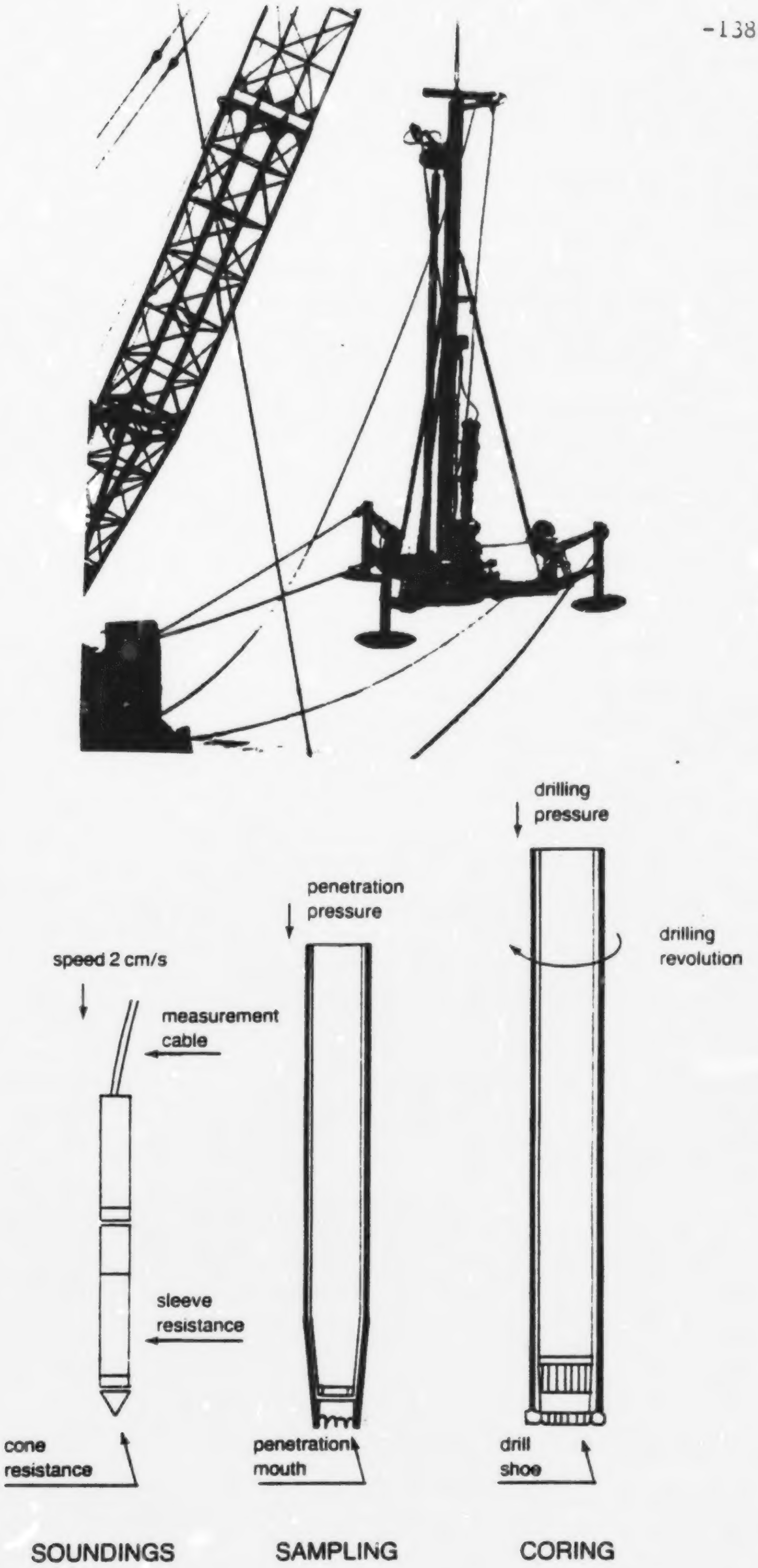

drilling pressure
penetration pressure
drilling revolution
speed 2 cm/s
measurement cable
sleeve resistance
cone resistance
penetration mouth
drill shoe
SOUNDINGS
SAMPLING
CORING

Figure 4.53

SEASAM (Seabed Sampler)

4.4.19 NORDCO Auger Drill (SEADRILL II) (Figure 4.54)

This equipment was developed by NORDCO during the period 1982 to 1985 (Capps and Ross 1986).

SEADRILL II is a seafloor mounted, remotely operated platform which is capable of taking a 75 mm diameter sediment core or 25 mm rock core up to 6.0 m long in 2,000 m of water. The drill weighs approximately 2,000 kg in air and up to 2,000 kg of ballast may be added if required.

The unit can operate in either a sediment sampling or rock coring mode. For sediment sampling, the core barrel is pushed into the soil while a rotating continuous flight auger follows closely behind acting as a casing for the barrel and reducing soil friction. By pushing the core barrel ahead of the auger a relatively undisturbed sample is obtained. If the core barrel is not able to penetrate a particular layer of material, the auger is allowed to bore ahead of it until the core barrel can once again penetrate the soil. In the rock coring mode, the system can drill through up to 6 m of overburden using the augering system. Upon reaching the bedrock, the system then engages the rock coring tool to penetrate with the rock core barrel an additional 6 m into the bedrock taking a 25 mm diameter core. A seawater flushing system is employed during rock coring operations.

The system is composed of the following major components:

- a modular, triangular, lattice-frame tower derrick mounted on a triangular base frame;
- three extendable legs with spade feet, by means of which the effective side length of the support base can be increased from 2.1 to 3.7 m;
- an all-electric power system, utilizing a 460V, 60 Hz, 3-phase shipboard supply fed via a composite coaxial electro-mechanical cable to three controlled submersible electric motors on the drill platform;

- two vertical drive plates which can be moved independently up and down inside the drill derrick;

- a rotating and reversible continuous flight hollow stem auger which is mounted on the lower vertical drive plate and is used to penetrate soil deposits;

- a non-rotating soil sample tube with inner liner which in the "soil sampling" mode is suspended from the upper vertical drive plate, and which can be extended through the centre of the hollow stem auger and pushed into the soil ahead of the auger to obtain relatively undisturbed samples of unconsolidated sediments (soils).

- a custom-made rock core drill which can be mounted on the upper vertical drive plate, in place of the soil sample tube, and deployed through the centre of the hollow stem auger;

- cone penetration testing equipment which can also be mounted on the upper vertical drive plate and deployed through the hollow stem auger;

- a piston inside the soil sample tube to assist in sample recovery;

- a computer assisted control and monitoring system for drilling, sampling and in-situ testing operations, with real-time direct readout and mimic display of key operating parameters together with complete recording of all operating data for subsequent playback.

In its present state of development, SEADRILL II comprises a seafloor mounted, remotely operated platform which is capable of:

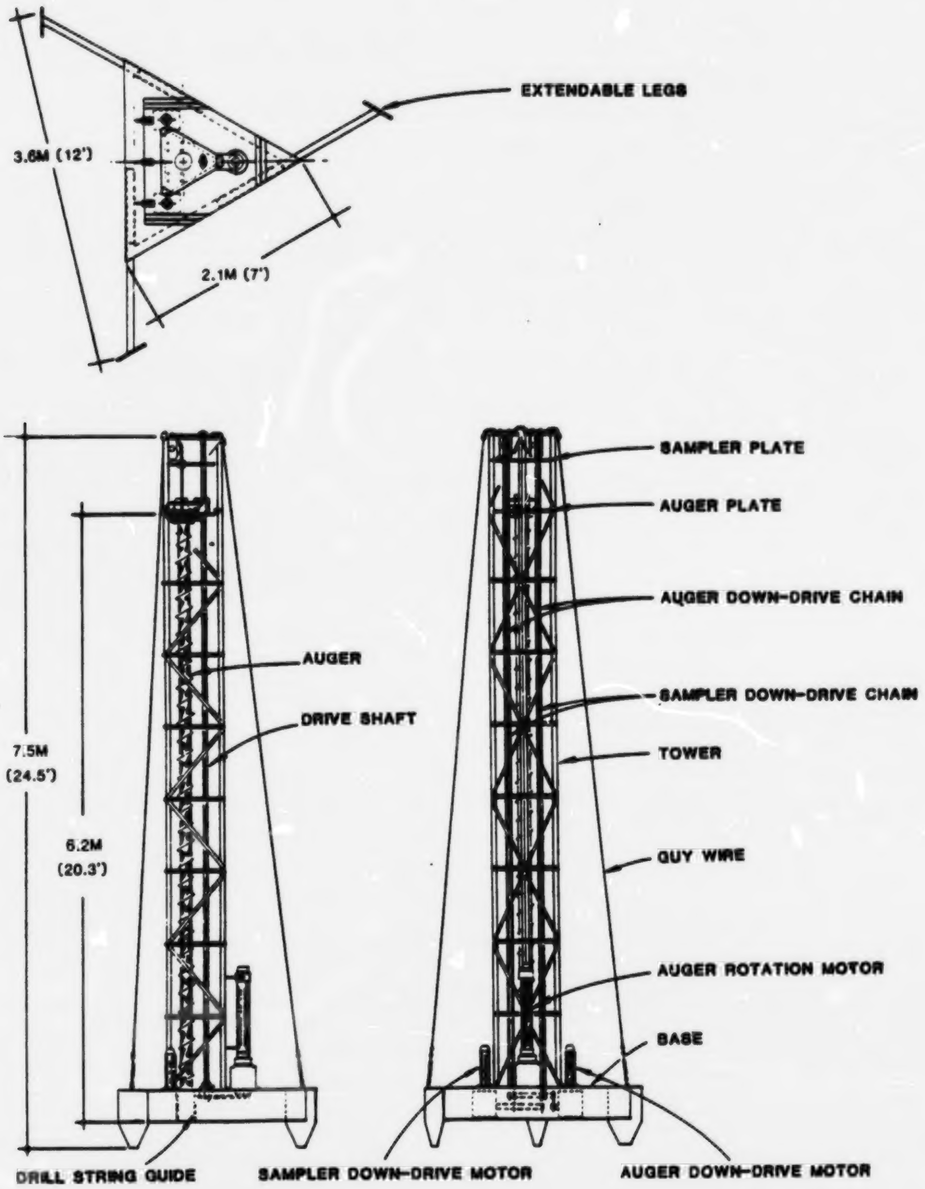
- drilling and sampling a wide range of seafloor soils ranging from soft muds to very dense gravels to a depth of 6 m below seabed;

- diamond core drilling of bedrock to a depth of 6 m below the seafloor;

- penetration of up to 6 m depth in unconsolidated (soil) sediment followed by diamond core drilling of bedrock to a further 6 m depth below the seafloor.

The present maximum design operating water depth of the system is 2,000 m. The drill has been tested, and has operated successfully in water depths of up to 800 m.

Recent development of the system during 1986 has added the capability of carrying out in-situ cone penetration tests (CPT) in sand, silt and clay deposits to a depth of 6 m below seabed. Sea trials of the CPT equipment are planned for 1987. Future development may include the addition of in-situ shear vane testing tools, and increased depth capability for CPT testing.


EXTENDABLE LEGS
3.6M (12')
2.1M (7')
7.5M
(24.5')
6.2M
(20.3')
AUGER
DRIVE SHAFT
SAMPLER PLATE
AUGER PLATE
AUGER DOWN-DRIVE CHAIN
SAMPLER DOWN-DRIVE CHAIN
TOWER
GUY WIRE
AUGER ROTATION MOTOR
BASE
DRILL STRING GUIDE
SAMPLER DOWN-DRIVE MOTOR
AUGER DOWN-DRIVE MOTOR

SCHEMATIC OF SUBSEA AUGER DRILL UNIT

Figure 4.54

NORDCO Auger Drill
(SEADRILL II)

4.5 JET AIRLIFT SAMPLERS

This type of equipment is widely used to prospect for marine sand and gravel deposits. A jetting pipe is suspended by a cable and lowered to the seabed. Separate flexible hoses supply air and water under pressure to near the base of the jetting pipe and the soil cuttings travel up the jetting pipe and then by another flexible hose to the surface vessel. Samples are taken at appropriate depth intervals from the soil/air/water mixture returned continuously to the surface. These samples are allowed to stand so that the solids settle and surplus water can then be decanted off.

With some systems, a pneumatic hammer is mounted on the jetting pipe to facilitate penetration of dense or cemented materials. Air lift systems are capable of providing a disturbed bulk sample comprising the complete sediment column to a depth of 10 to 15 m and, from this, selected samples may be extracted at specified depth intervals.

Adaptations of this concept have been used with vibratory and rotary sampling systems to provide a continuous disturbed sample directly to the surface.

Two jet airlift systems were examined as part of this study. Details of these systems are given in the following sections, and in Table 4.4.

TABLE 4.4 JET AIRLIFT SYSTEMS

	SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
1.	Ocean Science and Engineering Jet Airlift System	Sediments, clay gravel, sand, (unconsolidated)	46 m	Continuous sampling through 76mm stinger coretube up to 10.7m	Unknown	6.1m high stinger	Direct control from vessel, fully instrumented	Unknown	No	Uses water jet and air lift. Problems with holes caving in and resulting over-recovery. Completely disturbed sampling.
2.	Alluvial Mining AMdril	Sediments, clay gravel, sand, unconsolidated	150m	Continuous sampling through 150mm to 940 mm dia. barrels to 30 m.	Approx. 20,000 kg		Direct control from ship. Fully instrumented	600 cfm air compressor 250 gpm water pump 20 ton winch	No	Uses water jet and air lift. Pneumatic hammering available to aid penetration Can lift cobbles 150mm dia. Problems in sampling through clay beds. Completely disturbed sampling. Some over-recovery but not a major problem.

4.5.1 Ocean Science and Engineering Jet Airlift Systems (Figure 4.55)

The equipment was developed in 1968 by Ocean Science and Engineering and was manufactured and operated by the same company until they recently went out of business.

The system consists of a 6.1 m long, 76 mm I.D. rigid stinger which penetrates the ocean floor and is connected to the support vessel by a flexible hose. A high pressure water jet is used to loosen the soil and clear the way for the stinger. Air is injected into the stinger to lift the air/water/soil mixture to the vessel through the flexible hose.

It can sample up to 10.7 m of unconsolidated sediments in up to 46 m of water. The air lift system functions less efficiently in the shallower water depths.

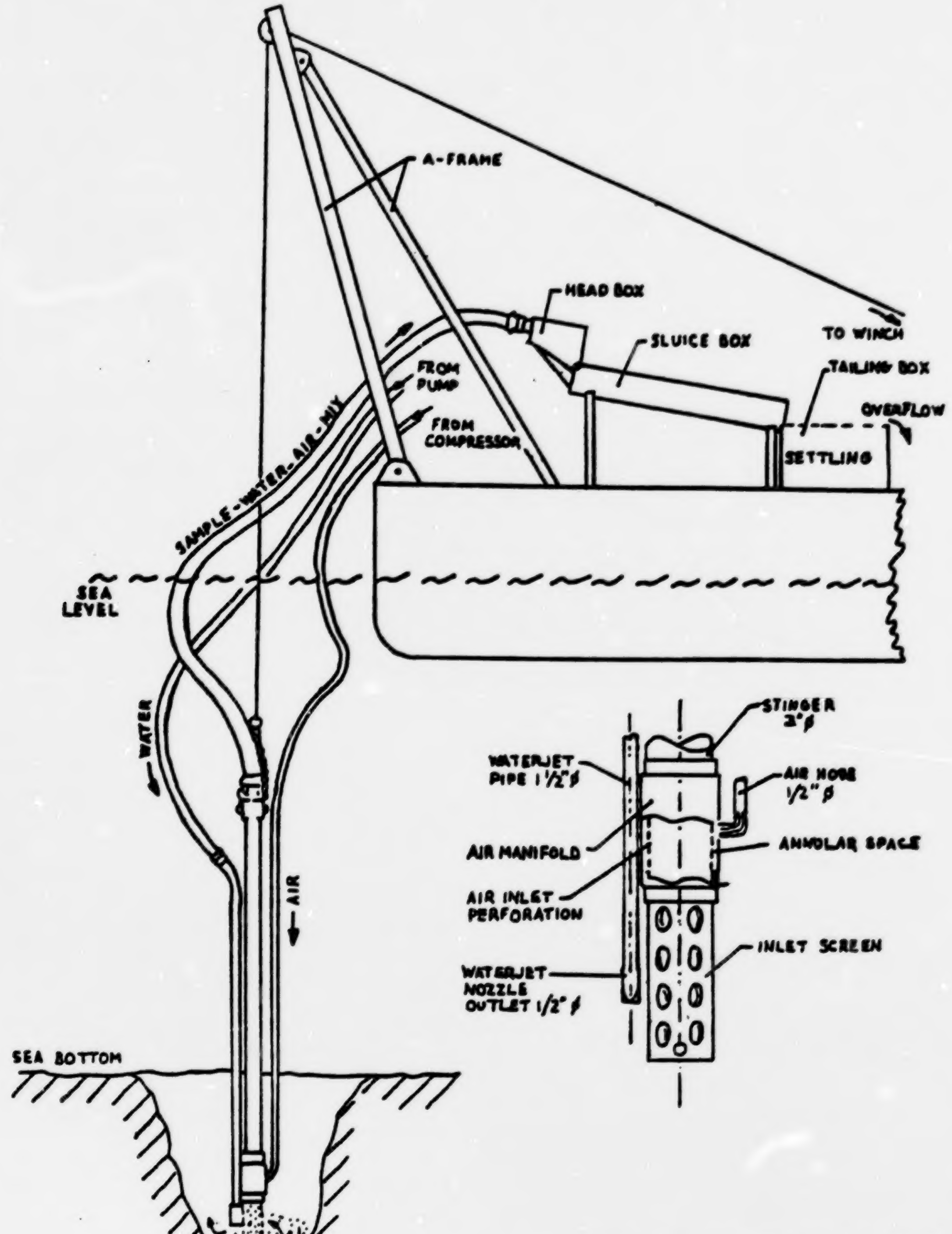
The equipment can be operated from small (12 m) support craft which must use at least a two point mooring system. The stinger is supported from the vessel by an A-frame, winch and cable.

Dimock (1986) reports that Ocean Science and Engineering used the system offshore Nova Scotia in 1968 to carry out mineral exploration for Matachewan Canadian Gold Limited from the 26.2 m vessel M/V Polarfish. One hundred and eighty seven holes were completed (out of 233 attempted) in a two-month period. Sediment depths ranged from 0.3 m to 10.7 m and water depths were between 9.1 m and 45.7 m. Total cumulative drilling depth was about 440 m.

Several problems were identified. Because the stinger is surface supported, the system is sensitive to vessel heave (maximum tolerable swell about 1 m) and also lateral motion. It is also felt that the air lift system may not be able to lift the denser "heavy metals" and they may migrate ahead of the sampler. This is a serious drawback in the context of sampling of gold-bearing placer deposits.

Caving of the sides of the hole is also a potential problem. As the stinger samples it forms a crater which is continuously enlarging. This process makes it impossible to identify any soil sample as coming from a particular stratum or precise depth below seabed. This is also a potentially serious drawback in the present context. The system is reportedly not able to penetrate material containing a significant proportion of cobbles and boulders.

JET AIRLIFT SAMPLING & PROCESSING SYSTEM


A-FRAME
HEAD BOX
SLUICE BOX
TO WINCH
TAILING BOX
OVERFLOW
FROM PUMP
FROM COMPRESSOR
SETTLING
SAMPLE-WATER-AIR-MIX
SEA LEVEL
WATER
AIR
SEA BOTTOM
STINGER 2"ϕ
WATERJET PIPE 1½"ϕ
AIR HOSE ½"ϕ
AIR MANIFOLD
ANNULAR SPACE
AIR INLET PERFORATION
INLET SCREEN
WATERJET NOZZLE OUTLET ½"ϕ

The Jet Airlift System (OSE, 1968)
(Reproduced from Dimock 1986)

Figure 4.55

Ocean Science and Engineering
Jet Airlift System

4.5.2 Alluvial Mining AMdril (Figure 4.56)

Developed, manufactured and marketed by Alluvial Mining and Shaft Sinking Company of Basildon, Essex, England.

The system was developed primarily for evaluating mineral bearing alluvial deposits and can recover materials containing cobbles up to 150 mm in diameter. The system can operate in water depths up to 150 m and can penetrate the seabed up to 15 m. The standard coring tube is 150 mm diameter (Alluvial Mining, Undated).

The unit is a combined water-jetting/continuous-sampling/airlift system, with a pneumatic hammer to assist in penetration of dense soils. Water and air are supplied from the support vessel and the sample is continuously returned to the sample catchment area on the vessel. Up to 1150 l/min of water and 17 m^3/min of air may be required. Water jets located around the periphery of the core barrel break up and entrain the sample into the suction orifice. Air is injected above the orifice to lift the slurry to the surface. The pneumatic hammer is used to aid penetration in difficult (i.e. dense or cemented) materials. It is located in a watertight housing on top of the drill head and exhaust air is vented to the surface.

Electronic instrumentation is used to record two functions of tool behaviour, i.e. drill penetration and inclination. The read out and recording units are housed in a weatherproof console adjacent to the operator's position on the drill ship.

The drill is normally operated from a sea-going vessel of about 500-600 tons.

The support vessel requires at least a single point mooring system from the bow and a heave compensation system with a minimum vertical travel of 4 m is required to support the drill pipe. At least one 20 tonne winch is required for lowering and raising of the drillpipe.

The system was used by Alluvial Mining off the eastern coast of Australia and Tasmania in 1967-8 to evaluate potential offshore gold, rutile and tin deposits in water depths generally about 20 m, but up to 50 m in places. During this program, the system sampled silts, clays and hard, compact sands (Alluvial Mining, Undated).

The AMdril system was also used during trials in St. Austell Bay during 1983 for tin placer exploration for Billiton Minerals, U.K. During this work, it is reported that the unit repeatedly clogged in clay beds overlying the pay zone (Seacore 1986).

AMdril has been used extensively in the U.K. for evaluation of offshore sand and gravel deposits and seems to perform well in gravelly material.

Recording transducers, located at the drill head, are installed in a fully pressure-compensated oil filled steel housing with external plug/socket connections.

The physical collection of selected sample material is achieved by a pneumatically operated valve and surge tower located at the sample collection station. Samples are normally collected in mobile containers of 5 cubic feet capacity at a frequency determined by the information required from the borehole.

Air and water supply to the drill is controlled by the drill operator and adjusted as necessary to the working water depth.

The 1986 lease cost for the AMdril system, including vessel and operator, is $5,000 (Canadian) per day (Alluvial Mining 1986).

Table 2: Analysis of drilling results achieved by 50-ft. AMdril in 160 ft. of water during winter months over a two week period

Day	Footage	Depth Max.	 Min.	Material	Average sea state (Feet)	Estimated wind speed (Beaufort)	Holes
1	19	12	2	Sand/Gravel	4-10	5-7	3
2	Nil	Nil	Nil	Nil	10-15	7-8	Nil
3	158	20	1	Sand/Gravel	5-12	2-4	15
4	43	17	5	"	6-12	3-5	5
5	97	21	1	"	3-4	3-4	10
6	108	18	1	"	3-4	1-2	10
7	48	14	2	"	3	3	6
8	50	18	1	"	3-4	1-3	7
9	90	17	3	"	1-2	2	10
10	25	7	2	"	1-6	2-4	6
11	147	33	1	"	3-4	4	11
12	Nil	Nil	Nil	Nil	6-10	6-7	Nil
13	Nil	Nil	Nil	Nil	6-10	6-7	Nil
14	103	38	30	Sand/Gravel	3-5	3-4	3

Specification

Barrel sizes:
150mm, 250mm, 450mm
Seabed penetration:
6m, 10m, 12m, 15m
Compressor: 600 cfm
Water pump: 250 gpm
Winch: 20 tons
Sample settling tubs
Swell compensation
Sample splitter
Control console
Depth/time penetration recorder
Coaster-type vessel
One-point mooring

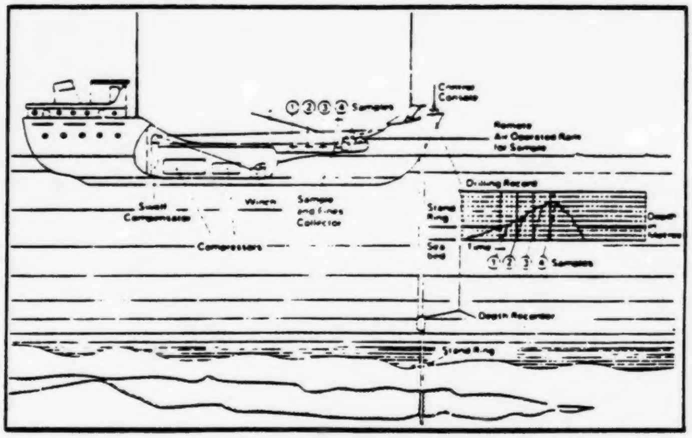

Control Console
① ② ③ ④ Samples
Remote Air Operated Ram for Sample
Drilling Record
Swell Compensator
Winch
Sample and Fines Collector
Stand Ring
Depth in Metres
Time
Sea bed
Compressors
① ② ③ ④ Samples
Depth Recorder
Stand Ring

FIGURE 4.56 Alluvial Mining AMdril

4.6 HAMMER DRILLS

4.6.1 Becker Hammer Drill (Figure 4.57 and Table 4.5)

Designed and manufactured by Becker Drills Inc., Commerce City, Colorado and Calgary, Alberta.

The Becker Hammer Drill utilizes a diesel pile hammer to drive a double-walled casing into the ground while, at the same time, air and/or water under pressure is delivered to the bottom of the hole through the annual space between the inner and outer walls of the casing. A special toothed bit at the base of the casing breaks the material being penetrated into small pieces. These pieces are removed by the air or water which returns to the surface via the inner casing, thus providing a continuous disturbed sample of the materials penetrated.

The basic elements of the system comprise an air compressor, a mud pump, a diesel pile hammer, a rotary drive unit, a hydraulic hoist, a casing puller, a mast, a cyclone for the collection of samples, and lengths of double wall steel casing (see Figure 4.57) (Becker, Undated).

The major advantages of the system are the rapid penetration rate which can be achieved and its ability to penetrate material containing cobbles and/or boulders. Hole depths of up to 76 m have been accomplished on land with penetration speeds up to 15.2 m/hour. The 140 mm double wall drill pipe will allow use of a standard rotary drill to take bedrock samples (Becker 1986). Drill pipe removal at the completion of the hole is achieved by a 50 tonne jacking system.

The system was designed for drilling and sampling on land and has been used with success on numerous projects. Use of the system has subsequently been extended to offshore applications. Use offshore requires that the casing extend above water and a derrick be used for joining additional lengths of pipe. If the rotary feature is to be used offshore, some form of heave compensation system may be required.

The system is relatively large and heavy (11.5 tonnes for drill unit) and for over water work a moonpool or "over-the-side" cantilevered work platform is required. For offshore work the equipment manufacturer recommends mounting the drill on a jack-up barge to provide a stable working platform and reduce weather dependency. However, this limits the maximum working water depth (Becker 1986).

In 1967, a Becker drill was used from the 62.5 m R/V Virginia City for mineral exploration off Nome, Alaska. A four-point mooring system was used, which required help from a support vessel for setting of anchors. Significant lateral vessel motion could not be tolerated. Forty holes were completed to an average depth of 20.7 m in 14 m of water. A diver-set seafloor jacking arrangement was necessary to retrieve the drill pipe on completion of drilling (Dimock 1986). Becker drills have also been used for tin exploration off Thailand (Dimock 1986).

TABLE 4.5 HAMMER DRILLS

	SAMPLER NAME	SOILS CORED	MAXIMUM WATER DEPTH	MAX. CORE LENGTH/DIA	WEIGHT (IN AIR)	MAX. HEIGHT AND WIDTH	INSTRUMENTATION	POWER REQUIREMENTS	CORE BARREL RETRACTION	REMARKS
1.	Becker Hammer Drill	Unconsolidated sand, clay, sediment, gravel and top layers of bedrock	Depends on maximum hgt. of unsupported drill string and lifting capacity of vessel	76 m / 140mm Continuous reverse flush sampling. Return to support vessel.	Unknown Varies with amt. of drill pipe required	Depends on number of drill rods required. Shipboard derrick required	None (Direct control from ship)	Coring is by diesel pile hammer. Other requirements unknown	Yes (50-ton hydraulic seafloor jack)	Reverse circulation diesel powered pile hammer principle Developed for on-land use. Offshore use requires pipe to extend above water level and a shipboard derrick to to handle pipe. Successfully used in Nome, Alaska, for placer evaluation. Rotary table is an option.

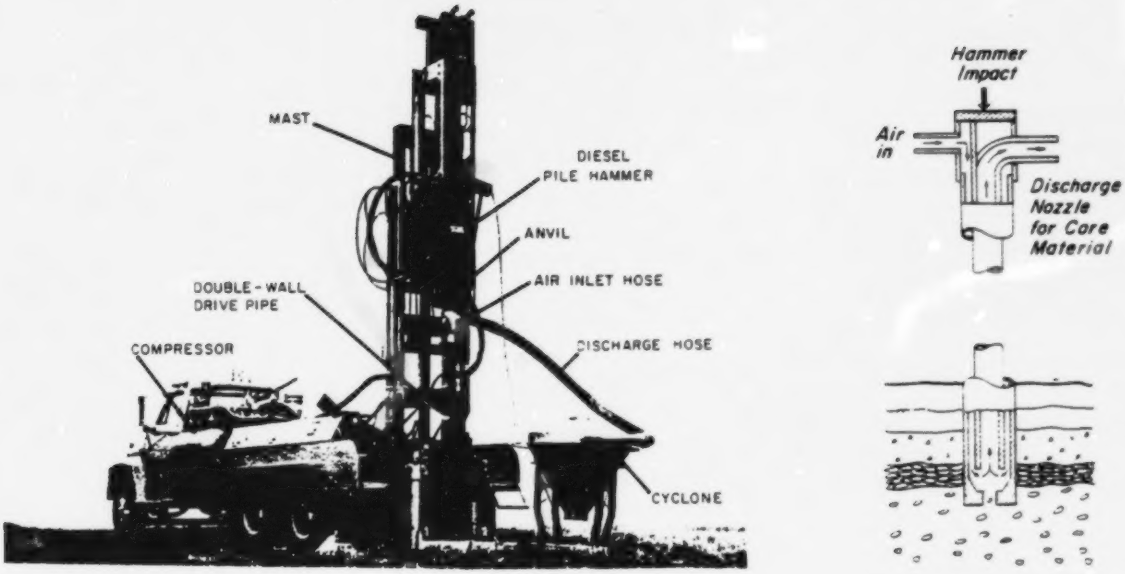

MAST
DIESEL
PILE HAMMER
ANVIL
DOUBLE-WALL
DRIVE PIPE
AIR INLET HOSE
COMPRESSOR
DISCHARGE HOSE
CYCLONE
Hammer
Impact
Air
in
Discharge
Nozzle
for Care
Material

Figure 4.57 Becker Hammer Drill

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APPENDIX A

SELECTED EQUIPMENT MANUFACTURERS

CONTACT NAMES AND ADDRESSES

Section No.	Equipment Name	Manufacturer/Supplier
4.3.1	B.G.S. - Aimers McLean Vibrocorer	British Geological Survey Marine Surveys Directorate Murchison House West Mains Road Edinburgh EH9, 3LA Telephone: 031-667-1000 Telex: 727343 Attention: Mr. Jack Pheasant
4.3.6	Geodoff I	Arkana Europe B.V. Wilhelminaplantsoen 122 P.O. Box 286, 1110AG Diemen Amsterdam, Holland Telephone: 020-90 62 96 Telex: 13399 Attention: Mr. Jr. R. Alders
4.3.7	Geodoff I Mark II	
4.4.2	Geodoff II	
4.4.15	Banka Drills	
4.3.8	BRGM - V4S8 Vibrocoring Device	Bureau de Recherches Geologiques et Minieres Avenue de Concyr Orleans - la Source (Loiret) B.P. 6009 - 45060 Orleans Cedex France Telephone: 38 63 80 01 Telex: 780258 Attention: Mr. L. Galtier
4.3.9	Rokleng Air Hammer	Seabed B.V. P.O. Box 335 1970 AH Ijmuiden
4.3.10	Seabed Vibrocorers	

4.3.11	Geomarex P1, P2, P3, P4 Vibrocorers	Geomarex P.O. Box 2244, La Jolla, California 92038 Telephone: (619) 459-6984 Telex: 192-820 Attention: Mr. Randall Pollack or Mr. Andre Rosfelder
4.3.19	Geomarex Hummingdrill Vibrocorer	
4.3.14	Haamer Vibrocorer	Manufactured by: Borros AB Box 3063, S-171 03 Salna, Sweden Telephone: 468-27 26 20 Telex: 11669 Attention: Mr. Owe Sundquist Canadian Distributer Sonic Soil Sampling Inc. 702-100 Adelaide St. West Toronto, Ontario M5H 1S3 Telephone: 416-363-5054 Attention: Mr. John Archibald
4.3.15	Alluvial Mining Vibrocorer	Alluvial Mining and Shaft Sinking Company Northgate House 2 High Pavement Basildon, Essex 5514 - 1EA, England Telephone: 0268-27382 Telex: 995 122 Attention: Mr. John Wenlock
4.5.2	Alluvial Mining Amdrill	

4.3.16	Alpine Vibracore	Alpine Ocean Seismic Survey, Inc. 80 Oak Street, Norwood New Jersey, 07648 Telephone: 201-768-8000 Telex: 135 705 Attention: Mr. Henry Miller
4.3.17	Wink Vibra Core	Sonic Soil Sampling Inc. 702-100 Adelaide St. West Toronto, Ontario M5H 1S3 Telephone (416) 363-5054 Attention: Mr. John Archibald Vi-Cor Technologies Inc. 400-601 West Cordova Street Vancouver, B.C. Telephone: (604) 684-4994 Fax: (604) 687-3478
4.3.18	Horton Vibrocorer	Ocean Science and Engineering* 3 Choke Cherry Road Rockville, Maryland 20850 * Note: Company has gone out of business.
4.5.1	Ocean Science and Engineering Jet Airlift System	
4.4.6	C-CORE Geotechnical Corer	C-CORE Memorial University of Nfld. St. John's, Nfld. A1B 3X5 Telephone: (709) 737-8359 Telex: 016-4101 Attention: Mr. Denny Christian

4.4.9 NORDCO Electric Rock Core Drill

4.4.19 NORDCO Auger Drill (SEADRILL II)

NORDCO Limited
P.O. Box 8833
St. John's, Newfoundland
A1B 3T2

Telephone: (709) 364-1200
Telex: 016 4596

Attention: Mr. John Capps

4.4.16 BSM12 Underwater Frame

CREO
Allee des Tamaris
17000 La Rochelle, France

Telephone: 46 41 13 13
Telex: 791 779

4.4.17 DGD 2000 Motion Compensated Deep Geotechnical Drill

Mobile Augers and Research Ltd.
5736 - 103A Street
Edmonton, Alberta
T6H 2J5

Telephone: (403) 436-3960

Attention: Mr. Ron Innis

4.4.18 SEASAM

Osiris-Cesco Ltd.
18, Deeside Industrial Estate
Welsh Road, Deeside
Clwyd CH5 2LR, U.K.

Telephone: 0244 816732

Telex: 61437

Osiris-Cesco bv
20, Rosmolenweg
P.O. Box 159
3350 AD Papendrecht
The Netherlands

Telephone: (078) 11 19 33
Telex: 20866

	SONICO Drill (Not listed in report. Could not gather info. as equipment is no longer manufactured)	Hawker Siddeley Canada Inc. P.O. Box 80 Station M, Montreal Quebec H1V 3L7 Telephone: 255-4041 Telex: 05-8287 34
4.6.1	Becker Hammer Drill	Becker Drills Inc. 11465 N. Highway 2 P.O. Box 567 Commerce City, CO 80037-0567 Telephone: (303) 286-7776 Telex: 45 888 Attention: Mr. Oscar E. Farris Becker Drills Inc. c/o Challenger International Services Ltd. 1000-715 5th Ave. S.W. Calgary, Alberta Telephone: (403) 269-3121 Telex: 03-825576